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MANUAL

OF

MINERALOGY AND PETROGRAPHY;

CONTAINING

The Elements of the Science of Minerals and Rocks.

FOR THE USE OF

THE PRACTICAL MINERALOGIST AND GEOLOGIST AND FOR INSTRUCTION IN SCHOOLS AND COLLEGES.

By JAMES D. DANA.

FOURTH EDITION.

REVISED THROUGHOUT AND ENLARGED.

ILLUSTRATED BY NUMEROUS WOOD-CUTS.

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PREFACE.

THE preface to the third edition of this work (1878) is as follows:

"This Manual in its present shape is new throughout. In the renovation it has undergone, new illustrations have been introduced, an improved arrangement of the species has been adopted, the table for the determination of minerals has been reconstructed, and the chapter on Rocks has been expanded to a length and fulness that renders it a prominent part of the work. But while modified greatly in all its parts, it is still simple in its methods of presenting the facts in crystallography, and in all other explanations; and special prominence is given, as in former editions, to the more common minerals, with only a brief mention of others. The old practical feature is retained of placing the ores under the prominent metal they contain, and of giving in connection some information as to mines and mining industry.

"The student is referred to the Text-book of Mineralogy, prepared mainly by Mr. E. S. DANA, for a detailed exposition of the subject of crystallography after Naumann's and Miller's systems, and also of optical mineralogy and other physical branches of the science; to the Manual of Determinative Mineralogy and Blowpipe Analysis by Professor GEORGE J. BRUSH, for a thorough work on the use of the blowpipe, and complete tables for the determination of minerals; and to the author's Descriptive Mineralogy and its Appendixes for a comprehensive treatise on minerals."

In this, the fourth, edition the general plan and scope of the work remain unchanged. But it has been revised throughout, and brought down to the year 1886 in its descriptions of minerals, and in the introduction of the many new species announced during the past eight years. The chapter on Rocks has been rewritten, rearranged, much enlarged, and supplied with new illustrations. The work is greatly indebted, for facts about ores and other useful minerals, to the excellent annual report on the "Mineral Resources of the United States," by Mr. Albert Williams, Jr., published by the United States Geological Survey. The author would acknowledge also his obligations to Prof. B. J. Harrington, of Montreal, for the revision of the list of localities in Ontario and Quebec.

JAMES D. DANA.

NEW HAVEN, Dec. 15, 1886.

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MINERALOGY.

MINERALS.

MINERALS are the materials of which the earth consists, and plants and animals the living beings over the surface of the mineral-made globe. A few rocks, like limestone and quartzite, consist of a single mineral in more or less pure state; but the most of them are mixtures of two or more minerals. Through rocks of each kind various other minerals are often distributed, either in a scattered way, or in veins and cavities. Gems are the minerals of jewelry; and ores, those that are important for the metal they contain. Water is a mineral, but generally in an impure state from the presence of other minerals in solution. The atmosphere, and all gaseous materials set free in volcanic and other regions, are mineral in nature, although, because of their invisibility, seldom to be found among the specimens of mineral cabinets. Even fossils are mineral in composition. This is true of coal which has come from buried plant-beds, and amber from the buried resin of ancient trees, as well as of fossil shells and corals.

It is sometimes said that minerals belong to the *mineral kingdom*, as plants to the vegetable kingdom, and animals to the animal kingdom. Substituting the term *inorganic* for mineral, the statement is right; for, as there are the two kingdoms of life, so there is in Nature what may be called a kingdom, or grand division, including all species not made through the organizing principle of life. But this inorganic kingdom is not restricted to minerals; it embraces all species made by inorganic forces; those of the earth's crust or surface, and, also, whatever may form under the manipulations of the chemist. The laws of composition and structure, exemplified in the constitution of rocks, are those also of the laboratory. A species made by

art, as we term it, is not a product of art, but a result solely of the fundamental laws of composition which are at the basis of all material existence; and the chemist only supplies the favorable conditions for the action of those laws. Mineral species are, then, but a very small part of those which make up the inorganic kingdom or division of Nature.

CHARACTERS OF MINERALS.

1. Minerals, unlike most rocks, have a definite chemical composition. This composition, as determined by chemical analysis, serves to define and distinguish the species, and indicates their profoundest relations. Owing to difference in composition, minerals exhibit great differences when heated, and when subjected to various chemical reagents, and these peculiarities are a means of determining the kind of mineral under examination in any case. The department of the science treating of the composition of minerals and their chemical reactions is termed CHEMICAL MINERALOGY.

2. Each mineral, with few exceptions, has its definite form, by which, when in good specimens, it may be known, and as truly so as a dog or cat. These forms are cubes, prisms, double pyramids, and the like. They are included under plane surfaces arranged in symmetrical order, according to mathematical law. These forms, in the mineral kingdom, are called *crystals*. Besides forms, there is also, as in living individuals, a distinctive internal structure for each species. The facts of this branch of the science come under the head of CRYSTALLOGRAPHIC MINERALOGY.

3. Minerals differ in *hardness*—from the diamond at one end of the scale to soapstone at the other. There is a still lower limit in liquids and gases; but of the hardness or cohesion in this part of the series the mineralogist has little occasion to take note.

Minerals differ in *specific gravity*, and this character, like hardness, is a most important means of distinguishing species.

Minerals differ in *color, transparency, lustre,* and other optical characters.

A few minerals have *taste* and *odor,* and when so these characters are noticed in descriptions.

The facts and principles relating to the above characters are embraced in the department of PHYSICAL MINERALOGY.

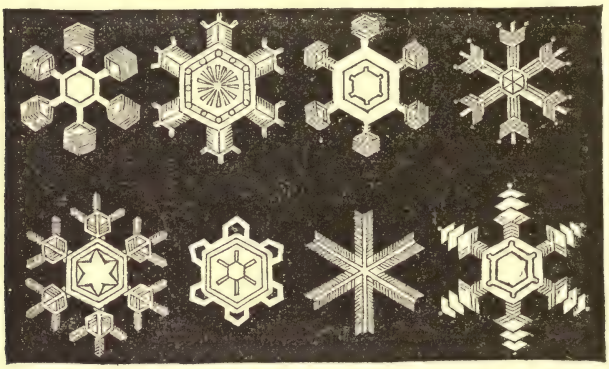
In addition to the above-mentioned branches of the science of minerals there is also (4) that of DESCRIPTIVE MINERALOGY, under which are included descriptions of the mineral species; and (5) that of DETERMINATIVE MINERALOGY, which gives a systematic review of the methods for determining or distinguishing minerals.

These different branches of the subject are here taken up in the following order: I. Crystallographic Mineralogy; II. Physical Mineralogy; III. Chemical Mineralogy; IV. Descriptive Mineralogy; V. Determinative Mineralogy. On account of the brief manner in which the subjects are treated in this volume, the heads used for the several parts are, (1) *The Crystallization of Minerals;* (2) *Physical Properties of Minerals;* (3) *Chemical Properties of Minerals;* (4) *Descriptions of Species;* (5) *Determination of Minerals.*

I. CRYSTALLIZATION OF MINERALS: CRYSTALLOGRAPHY.

1. General Remarks on Crystallization.

The attraction which produces crystals is one of the fundamental properties of matter. It is identical with the cohesion of ordinary solidification; for there are few cases outside of the kingdoms of life in which solidification takes place without some degree of crystallization. Cohesive attraction is, in fact, the organizing or structure-making principle in inorganic nature, it producing specific forms for each species of matter, as life does for each living species. A bar of cast-iron is rough and hackly in surface, because of the angular *crystalline* grains which the iron assumed as solidification took place. A fragment of mar-

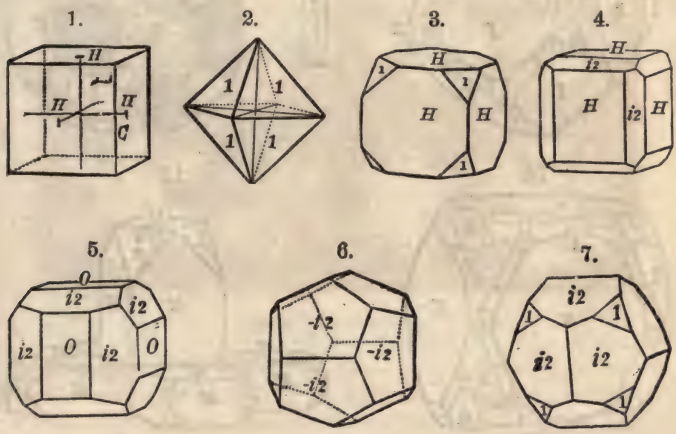


CRYSTALS OF SNOW.

ble glistens in the sun, owing to the reflection of light from innumerable crystalline surfaces, every grain in the mass having its crystalline structure. When the cold of winter settles over the earth in the higher temperate and colder latitudes it is the signal for crystallization over all out-door nature; the air is filled with crystal flakes when it snows; the streams become coated with an aggregation

of crystals called ice; and windows are covered with frost because crystal has been added to crystal in long feathered lines over the glass—Jack Frost's work being the making of crystals. Water cannot solidify without crystallizing, and neither can iron nor lead, nor any mineral material, with perhaps half a dozen exceptions. Crystallization produces masses made of crystalline grains when it cannot make distinct crystals. Granite mountains are mountains of crystals, each particle being crystalline in nature and structure. The lava current, as it cools, becomes a mass of crystalline grains. In fact the earth may be said to have crystal foundations; and if there is not the beauty of external form, there is everywhere the interior, profounder beauty of universal law—the same law of symmetry which, when external circumstances permit, leads to the perfect crystal with regular facets and angles.

Crystals are alone in making known the fact that this law of symmetry is one of the laws of cohesive attraction, and that under it this attraction not only brings the particles of matter into forms of mathematical symmetry, but often develops scores of brilliant facets over their surface



with mathematical exactness of angle, and the simplest of numerical relations in their positions. Crystals teach also the more wonderful fact that the same species of matter

may receive, under the action of this attraction, through some yet incomprehensible changes in its condition, a great diversity of forms—from the solid of half a dozen planes to one of scores. The above figures represent a few of the forms in a common species, pyrite, a compound of iron and sulphur.

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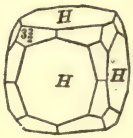

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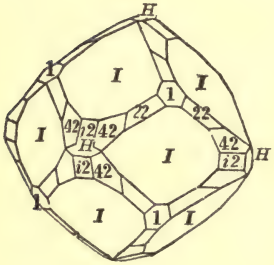

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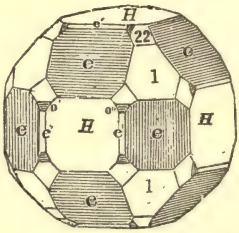

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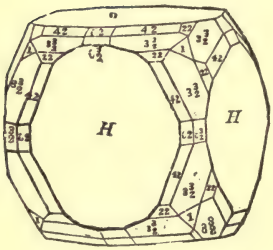

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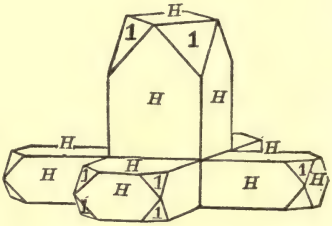


Many more figures might be given for this one species, pyrite. The various forms or planes in any such case have, it is true, mutually dependent relations—a fact often ex-

pressed by saying that they have a common *fundamental form*. But it is none the less a remarkable fact, giving profound interest to the subject, that the attraction, while having this degree of unity in any species, still, under each, admits of the multitudinous variations needed to produce so diverse results.

At the time of crystallization the material is usually in a state of fusion, or of gas or vapor, or of solution. In the case of iron the crystallization takes place from a state of fusion, and while the result is ordinarily only a mass of crystalline grains, distinct crystals are sometimes formed in any cavities. If in the cooling of a crucible of melted lead, bismuth, or sulphur the crust be broken soon after it forms, and the liquid part within be turned out, crystals will be found covering the interior. Here, also, is crystallization from a state of fusion. When frost or snow-flakes form it exemplifies crystallization from a state of vapor. If a saturated solution of alum, made with hot water, be left to cool, crystals of alum after a while will appear, and will become of large size if there is enough of the solution. A solution of common salt, or of sugar, affords crystals in the same way. Again, whenever a mineral is produced through the change or decomposition of another, and at the same time assumes the solid state, it takes at once a crystalline structure, if it does not also develop crystals.

Further, the crystalline texture of a solid mass may often be changed without fusion: *e.g.*, in tempering steel the bar is changed from coarse-grained steel to fine-grained by heating and then cooling it suddenly in cold water, and *vice versa*, and this is a change in every grain throughout the bar.

Thus the various processes of solidification are processes of crystallization, and the most universal of all facts about minerals is that they are crystalline in texture. A few exceptions have been alluded to, and one example of these is the mineral opal, in which even the microscope detects no evidence of a crystalline condition, except sometimes in minute portions supposed not to be opal. But if we exclude coals and resins this mineral stands almost alone. Such facts, therefore, do not affect the conclusion that a knowledge of crystallography is of the highest importance to the mineralogist. It is important because—

1. A study of the crystalline forms and structure of minerals is a convenient means of distinguishing species—the crystals of a species being essentially constant in structure and in angles.

2. The most important optical characters depend on the crystallization, and have to be learned from crystals.

3. The profoundest chemical relations of minerals are often exhibited in the relations of their crystalline forms.

4. Crystallization opens to us Nature at her foundation work, and illustrates its mathematical character.

2. Descriptions of Crystals.

In describing crystals there are two subjects for consideration: First, Form; and secondly, Structure.

A. Form.—Under *form* come up for description, not only the general forms of crystals, but also—

(1) The systems of crystallization, that is, the relations of *all* crystalline forms, and their classification.

(2) The mutual relations of the planes of a crystal as ascertained through their positions and the angles between them.

(3) The distortions of crystals. The perfection of symmetry exhibited in the figures of crystals, in which all similar planes are represented as having the same size and form, is seldom found in nature, and the true form is often greatly disguised by this means. The facts on this point, and the methods of avoiding wrong conclusions, need to be understood, and these are given beyond. With all such imperfections *the angles of crystals remain essentially constant*. There are irregularities also from other sources.

(4) Twin or compound crystals. With some species *twins* are more common than regular crystals.

(5) Crystalline aggregates, or combinations of imperfect crystals, or of crystalline grains.

Explanations of Terms.

The following are explanations of a few terms used in connection with this subject:

1. *Octahedron.*—A solid bounded by *eight* equal triangles. They are equal equilateral triangles in the *regular* octahedron (Fig. 2, p. 18); equal isosceles triangles in the *square* octahedron (Fig. 17, p. 33); equal inequilateral triangles in the *rhombic* octahedron (Fig. 8, p. 38).

2. *Double six-sided pyramids. Double eight-sided pyramids. Double twelve-sided pyramids.*—Solids made of two equilateral six-sided, or eight-sided, or twelve-sided, pyramids placed base to base (Fig. 20, p. 33, and 6, 10, pp. 48, 49).

3. *Right prisms. Oblique prisms.*—Right prisms are those that are erect, all their sides being at right angles to the base. When inclined, they are called *oblique* prisms.

4. *Interfacial angle.*—Angle of inclination between two faces or planes.

5. *Similar planes. Similar angles.*—The lateral faces of a square prism (Fig. 2, p. 15) are equal and have like relations to the axes, and hence they are said to be *similar*. Solid angles are *similar* when the plane angles are equal each for each, and the enclosing planes are severally similar in their relations to the axes.

6. *Truncated. Bevelled.*—An edge of a crystal is said to be *truncated* when it is replaced by a plane *equally* inclined to the enclosing planes, as in Fig. 13, p. 20; and it is *bevelled* when replaced by two planes equally inclined severally to the adjoining faces. Only edges that are formed by the meeting of two *similar* planes can be truncated or bevelled. The angle between the truncating plane and the plane adjoining it on either side always equals 90° *plus* half the interfacial angle over the truncated edge. When a rectangular edge, or one of 90°, is truncated, this angle is accordingly 135° (= 90° + 45°); when an edge of 70°, it is 125° (= 90° + 35°); when an edge of 140°, it is 160° (= 90° + 70°).

7. *Zone.*—A zone of planes includes a series of planes having the edges between them, that is, their mutual intersections, all parallel. Thus in Fig. 14, on page 6, *H* at top of figure, $i2$, $i\frac{3}{2}$, *H* in front, and two planes below, and others on the back of the crystal are in one zone, a vertical zone. Again, in the same figure, *H* at top, 42, $3\frac{3}{2}$, 22, 42, $i2$, 42, 22, $3\frac{3}{2}$, and the continuation of this series below and over the back of the crystal lie in another vertical zone. And so in cases in other directions. All planes in the same zone may be viewed as on the circumference of the same circle. The planes of crystals are generally all comprised in a few zones, and the study of the mathematics of crystals is largely the study of zones of planes.

Axes.—Imaginary lines in crystals intersecting one another at their centres. Axes are assumed in order to describe the positions of the planes of crystals. In each system of crystallization there is one *vertical* axis, and in all but hexagonal forms there are *two lateral* axes.

Diametral sections.—The sections of crystals in which lie any two of the axes. In forms having two lateral axes, there are two vertical diametral sections and one basal.

Diametral prisms.—Prisms whose sides are parallel to the diametral sections.

Measurement of Angles.

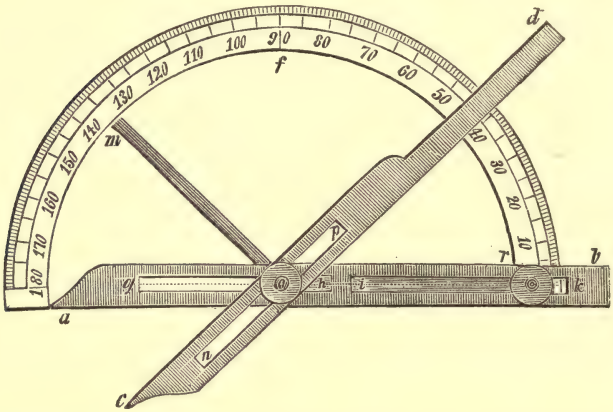
The angles of crystals are measured by means of instruments called *goniometers*. These instruments are of two kinds, one the *common goniometer*, the other, the *reflecting goniometer*.

The *common goniometer* depends for its use on the very simple principle that when two straight lines cross one another, as *AE, CD*, in the annexed figure, the parts will diverge equally on opposite sides of the point of intersection (*O*); that is, in mathematical language, the angle *AOD* is equal to the angle *COE*, and *AOC* is equal to *DOE*.

A common form of the instrument is represented in the figure below.

The two arms *ab, cd*, move on a pivot at *o*, and their divergence, or the angle they make with one another, is read off on the graduated arc attached. In using it, press up between the edges *ao* and *co* the edge of the crystal whose angle is to be measured, and continue thus opening the arms until these edges lie evenly against the faces that include the required angle. To insure accuracy in this respect, hold the instrument and crystal between the eye and the light, and observe that no light passes between the arm and the applied faces of the crystal. The arms may then be secured in position by tightening the screw at *o*; the angle will then be measured by the distance on the arc from *k* to the *left* or *outer* edge of the arm *cd*, this edge being in the line of *o*, the centre of motion. As the instrument stands in the figure, it reads 45°. The arms have slits at *gh, np*, by which the parts *ao, co*, may be shortened so as to make them more convenient for measuring small crystals.

In the best form of the common goniometer the arc is a complete



circle, of larger diameter than in the above figure, and the arms are separate from it. After making the measurement, the arms are laid upon the circle, with the pivot at the centre of motion inserted in a socket at the centre of the circle. The inner edge of one of the arms is then brought to zero on the circle, and the angle is read off as before.

With a little ingenuity the student may construct a goniometer for himself that will answer a good purpose. A semicircle may be described on mica or a glazed card, and graduated. The arms might also be made of stiff card for temporary use; but mica, bone, or metal is better. The arms should have the edges straight and accurately parallel, and be pivoted together. The instrument may be used like that last described, and will give approximate results, sufficiently near for distinguishing most minerals. The ivory rule accompanying boxes of mathematical instruments, having upon it a scale of sines for measuring angles, will answer an excellent purpose, and is as convenient as the arc.

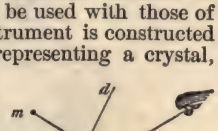
In making such measurements it is important to have in mind the fact that—

1. The sum of the angles about a centre is 360°.

2. In a rhomb, as in a square, the sum of the plane angles is 360°.

In any polygon, the *supplements of the angles equal* 360°, *whatever the number of sides.* For example: in a square, the four angles are each 90°, and hence the supplements are 90°, and $4\times90=360$; again, in a regular hexagon the six angles are each 120, the supplements are 60°, and $6\times60=360$. So for all polygons, whether regular or irregular. In measuring the angles it is therefore convenient to take down the supplements of the angles. This principle is conveniently applied in the measurement of all the angles of a zone of planes around the crystal; for the sum of all the supplements should be, as above, 360°, and if this result is not obtained there is error somewhere.

The *reflecting goniometer* affords a more accurate method of measuring crystals that have lustre, and may be used with those of minute size. The principle on which this instrument is constructed will be understood from the annexed figure, representing a crystal, whose angle *abc* is required. The eye, looking at the face of the crystal *bc*, observes a reflected image of *m*, in the direction *Pn*. On revolving the crystal till *ab* has the position of *bc*, the same image will be seen again in the same direction *Pn*. As the crystal is turned, in this revolution, till *abd* has the present position of *bc*, the angle *dbc* measures the number of degrees through which it is revolved. But *dbc* subtracted from 180° equals the angle of the crystal *abc*. The crystal is therefore passed, in its revolution, through a number of degrees equal to the supplement of the required angle.

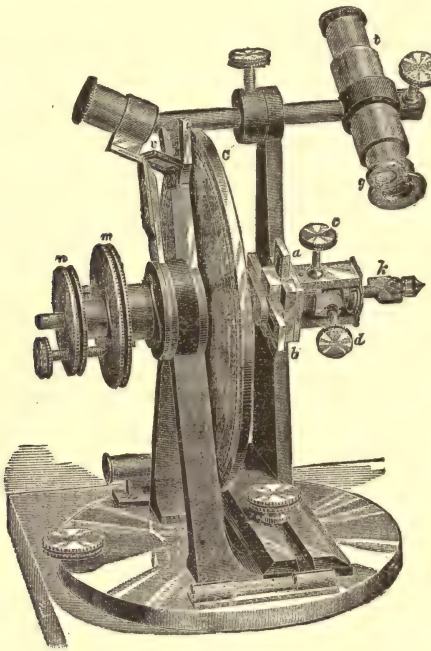


This angle, in the reflecting goniometer of Wollaston, one form of which is represented in the following figure, is measured by attaching the crystal to a graduated circle which revolves with it.

C is the graduated circle. The wheel, *m*, is attached to the main axis, and moves the graduated circle together with the adjusted crystal. The wheel, *n*, is connected with an axis which passes through the main axis (which is hollow for the purpose), and moves merely the parts to which the crystal is attached, in order to assist in its adjustment. The contrivances for the adjustment of the crystal are at *a*, *b*, *c*, *d*, *k*. The screws, *c*, *d*, are for the adjustment of the crystal, and the slides, *a*, *b*, serve to centre it.

To use the instrument, it may be put on a stand or small table, with its base accurately horizontal, and the table placed in front of a window, six to twelve feet off, with the plane of its circle at right angles to the window. A line must then be drawn below the window, near or on the floor, parallel to the bars of the window, and about as far from the eye as from the window-bar.

The crystal is attached to the movable plate k by means of wax, and so arranged that the edge of intersection of the two planes forming the



required angle shall be in a line with the axis of the instrument. This is done by varying its situation on the plate, or by means of the adjacent screws and slides.

When apparently adjusted, the eye must be brought close to the crystal, nearly in contact with it, and on looking into a face, part of the window will be seen reflected, one bar of which must be selected for the trial. If the crystal is correctly adjusted, the selected bar will appear horizontal, and on turning the wheel n, till this bar, as *reflected*, is observed to approach the dark line below seen in a *direct* view, it will be found to be parallel to this dark line, and ultimately to coincide with it. The eye for both observations should be held in

precisely the same position. If there is not a perfect coincidence, the adjustment must be altered until this coincidence is obtained. Continue then the revolution of the wheel *n*, till the same bar is seen by reflection in the next face, and if here there is also a coincidence of the reflected bar with the dark line seen direct, the adjustment is complete; if not, alterations must be made, and the first face again tried. In an instrument like the one figured, the circle is usually graduated to twenty or thirty minutes, and, by means of the vernier, minutes and half minutes are measured. After adjustment, 180° on the arc must be brought opposite 0, on the vernier, *v*. The coincidence of the bar and dark line is then to be obtained, by turning the wheel *n*. When obtained, the wheel *m* should be turned until the same coincidence is observed, by means of the next face of the crystal. If a line on the graduated circle now corresponds with 0 on the vernier, the angle is immediately determined by the number of degrees opposite this line. If no line corresponds with 0, we must observe which line on the vernier coincides with one on the circle. If it is the 18th on the vernier, and the line on the circle next below 0 on the vernier marks 125°, the required angle is 125° 18′; if this latter line marks 125° 20′, the required angle is 125° 38′.

In the better instruments other improved methods of arrangement are employed; and in the best, often called Mitscherlich's goniometer, because first devised by him, there are two telescopes, one for passing a ray of light upon the adjusted crystal, having crossed hair-lines in its focus, and the other for viewing it, also with a hair-cross. With such an arrangement, the window-bar and dark line are unnecessary, the hair-crosses serving to fix the position of the crystal, and the telescope that of the eye. If the crystal is perfect in its planes, and the adjustment exact, the measurement, with the best instruments, will give the angle within 10″.

Other goniometers have only the second of the two telescopes just alluded to, as is the case in the figure on page 12. This telescope gives a fixed position to the eye; and through it is seen a reflection of some distant object, which may be even a chimney-top. For the measurement the object, seen reflected in the two planes successively, is brought each time into conjunction with the hair cross. Exact adjustment is absolutely essential, and with an instrument having the two telescopes, the first step in a measurement cannot be taken without it.

Only small, well-polished crystals can be accurately measured by the reflecting goniometer. If, when using the instrument without telescopes, the faces do not reflect distinctly a bar of the window, the flame of a candle or of a gas-burner, placed at some distance from the crystal, may be used by observing the flash from it with the faces in succession as the circle is revolved. A ray of sunlight from a mirror, received on the crystal through a small hole, may be employed in a similar way. But the results of such measurements will be only approximations. With two telescopes and artificial light, and with a cross-slit to let the light pass in place of the cross-hairs of the first of the above mentioned telescopes, this light-cross will be reflected from the face of a crystal even when it is not perfect in polish, and quite good results may be obtained.

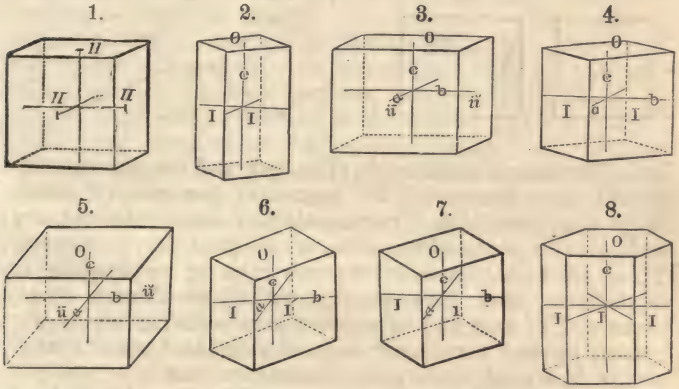
B. STRUCTURE.—Structure includes cleavage, a characteristic of crystals intimately connected with their forms and nature. It is the property, which many crystals have, of admitting of subdivision indefinitely in certain directions, and affording usually even, and frequently polished, surfaces. The direction is always parallel with the planes of the axes, or with others diagonal to these.

The ease with which cleavage can be obtained varies greatly in different minerals, and in different directions in the same mineral. In a few species, like mica, it readily yields laminæ thinner than paper, and in this case the cleavage is said to be *eminent*. Others, of *perfect* cleavage, cleave easily, but afford thicker plates, and from this stage there are all grades to that in which cleavage is barely discernible or *difficult*. The cleavage surfaces vary in lustre from the most brilliant to those that are nearly dull. When cleavage in a mineral is alike in two or more directions, that is, is attainable in these directions with equal facility and affords surfaces of like lustre and character or marking, this is proof that the planes in those directions are similar, or have similar relations to like axes. For example, equal cleavage in *three* directions, at *right angles* to one another, shows that the planes of cleavage correspond to the faces of the cube; so equal cleavage in *two* directions, in a prismatic mineral, shows that the planes in the two directions are those of a square prism, or else of a rhombic prism; and if they are at right angles to one another, that they are those of the former. This subject is further illustrated beyond.

In the following pages (1) the Systems of Crystallization and the Forms and Structure of Crystals are first considered; next, (2) Compound or Twin Crystals; (3) Paramorphs; (4) Pseudomorphs; and (5) Crystalline Aggregates.

1. SYSTEMS OF CRYSTALLIZATION: FORMS AND STRUCTURE OF CRYSTALS.

The forms of crystals are exceedingly various, while the *systems* of crystallization, based on their mathematical distinctions, are only *six* in number. Some of the simplest of the forms under these six systems are the prisms represented in the following figures; and by a study of these forms the



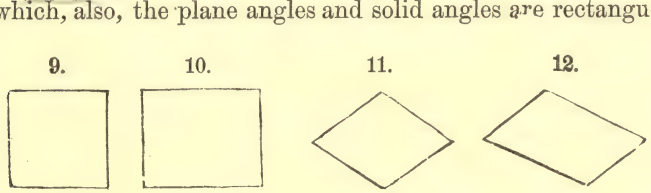
distinctions of the six systems will become apparent. These prisms are all four-sided, excepting the last, which is six-sided. In them the planes of the top and bottom, and any planes that might be made parallel to these, are called the *basal* planes, and the sides the *lateral* planes. An imaginary line joining the centres of the bases (*c* in Figs. 1 to 8) is called the *vertical axis*, and the diagonals *a* and *b*, drawn in a plane parallel to the base, are the *lateral axes*.

Fig. 1 represents a cube. It has all its planes square (like Fig. 9), and all its plane and solid angles, right angles, and the three axes consequently *cross at right angles* (or, in other words, make *rectangular intersections*) and are *equal*. It is an example under the first of the systems of crystallization, which system, in allusion to the equality of the axes, is called the *Isometric system*, from the Greek for *equal* and *measure*.

Fig. 2 represents an erect or right square prism having

all its plane angles and solid angles rectangular. The base is square or a tetragon, and consequently the *lateral axes are equal and rectangular in their intersections;* but, unlike a cube, *the vertical axis is unequal to the lateral.* There are hence, in the square prism, axes of two kinds making rectangular intersections. The system is hence called, in allusion to the tetragonal base, the *Tetragonal system.*

Fig. 3 represents an erect or right rectangular prism, in which, also, the plane angles and solid angles are rectangu-



lar. The base is a rectangle (Fig. 10), and consequently the *lateral axes,* connecting the centres of the opposite lateral faces, are *unequal* and rectangular in their intersections; and, at the same time, *each is unequal to the vertical.* There are hence three unlike axes making rectangular intersections; and the system is called, in allusion to the three unlike axes and in allusion also to its including erect prisms having a rhombic base, the *Orthorhombic system, orthos,* in Greek, signifying *straight* or *erect.*

This rhombic prism is represented in Fig. 4. It has a rhombic base, like Fig. 11; the lateral axes connect the centres of the opposite lateral edges; and hence they cross at right angles and are unequal, as in the rectangular prism. This right rhombic prism is therefore one in system with the right rectangular prism.

Fig. 5 represents another rectangular prism, and Fig. 6 another rhombic prism; but, unlike Figs. 3 and 4, the prisms are *inclined* backward, and are therefore *oblique* prisms. The lateral axes (a, b) are at right angles to one another and unequal, as in the preceding system; but the vertical axis is inclined to the plane of the lateral axes. It is inclined, however, to only one of the lateral axes, it being at right angles to the other. Hence, of the three angles of axial intersection, two are rectangular, namely, a on b, and c on b, while one is oblique, that is, c (the vertical axis) on a. In allusion to this fact, there being only *one* oblique angle,

this system is called the *Monoclinic* system, from the Greek for *one* and *inclined*.

Fig. 7 represents an oblique prism with a *rhomboidal* base (like Fig. 12). The three axes are unequal and the three axial intersections are *all oblique*. The system is called the *Triclinic* system, from the Greek for *three* and *inclined*.

Fig. 8 represents a six-sided prism, with the sides equal and the base a regular hexagon. The lateral axes are here three in number. They intersect at angles of 60°; and this is so, whether these lateral axes be lines joining the centres of opposite lateral planes, or of opposite lateral edges, as a trial will show. The vertical axis is at right angles to the plane of the three lateral axes, inasmuch as the prism is erect or right. The base of the prism being a regular hexagon, the system is called the *Hexagonal system*.

The systems of crystallization are therefore:

I. The ISOMETRIC system: the three axes rectangular in intersections; equal.

II. The TETRAGONAL system: the three axes rectangular in intersections; the two lateral axes equal, and unequal to the vertical.

III. The ORTHORHOMBIC system: the three axes rectangular in intersections, and unequal.

IV. The MONOCLINIC system: only one oblique inclination out of the three made by the intersecting axes; the three axes unequal.

V. The TRICLINIC system: all the three axes obliquely inclined to one another, and unequal.

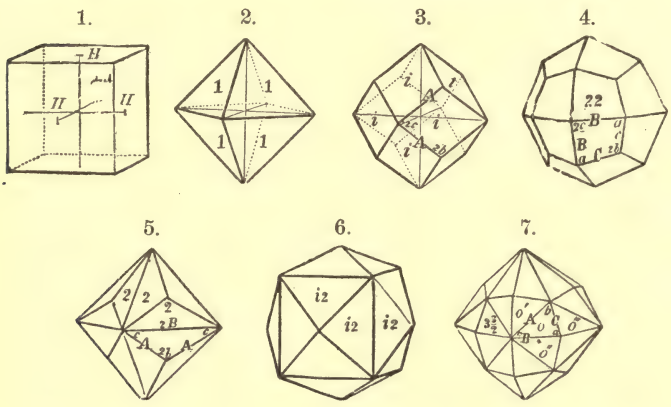
VI. The HEXAGONAL system: the vertical axis at right angles to the lateral; the lateral three in number, and intersecting at angles of 60°.

These six systems of crystallization are based on mathematical distinctions, and the recognition of them is of great value in the study and description of crystals. Yet these distinctions are often of feeble importance, since they sometimes separate species and crystalline forms that are very close in their relations. There are forms under each of the systems that differ but little in angles from some of other systems: for example, square prisms that vary but slightly from the cubic form; triclinic that are almost identical with monoclinic forms; hexagonal that are nearly cubic. Consequently it is found that the same natural group

of minerals may include both orthorhombic and monoclinic species, as is true of the Hornblende group; or monoclinic and triclinic, as is the fact with the Feldspar group, and so on. It is hence a point to be remembered, when the affinities of species are under consideration, that difference in crystallographic system is far from certain evidence that any species are fundamentally or widely unlike.

I. THE ISOMETRIC SYSTEM.

1. Descriptions of Forms.—The following are figures of some of the forms of crystals under the isometric system:



The first is the *cube* or *hexahedron*, already described. Besides the three cubic axes, there are equal diagonals in two other directions; one set connecting the apices of the diagonally opposite solid angles, *four* in number (because the number of such angles is eight), and called the *octahedral axes;* and another set connecting the centres of the diagonally opposite edges, *six* in number (because the number of edges is twelve), and called the *dodecahedral axes.*

Fig. 2 represents the *octahedron*, a solid contained under eight equal triangular faces (whence the name from the Greek *eight* and *face*), and having the three axes like those in the cube. Its plane angles are 60°; its interfacial angles, that is, the inclination of planes 1 and 1 over an intervening

edge (usually written $1 \wedge 1$) $= 109° 28'$ (more exactly $109° 28' 16''$); and 1 on 1 over a solid angle, $70° 32'$.

Fig. 3 is the dodecahedron, a solid contained under *twelve* equal rhombic faces (whence the name from the Greek for *twelve* and *face*). The position of the cubic axes is shown in the figure. It has fourteen solid angles; six formed by the meeting of four planes, and eight formed by the meeting of three. The interfacial angles (or i on an adjoining i) are $120°$; i on i over a four-faced solid angle $= 90°$.

Fig. 4 is a *trapezohedron*, a solid contained under 24 equal trapezoidal faces. There are several different trapezohedrons among isometric crystalline forms. The one here figured, which is the common one, has the angle over the edge B, $131° 49'$, and that over the edge C, $146° 27'$. A trapezohedron is also called a *tetragonal trisoctahedron*, the faces being tetragonal or four-sided, and the number of faces being 3 times 8 (*tris*, *octo*, in Greek).

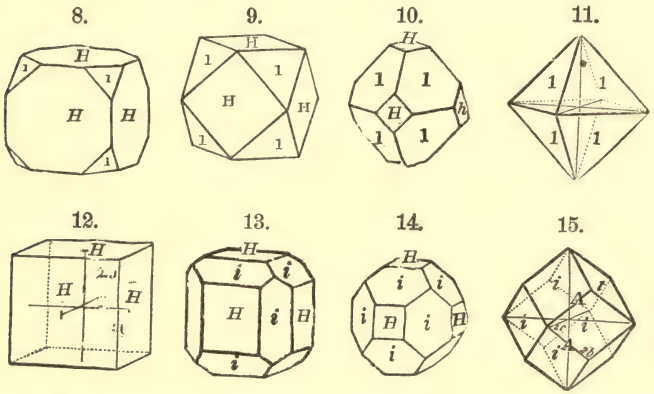
Fig. 5 is another trisoctahedron, one having trigonal or three-sided faces, and hence called a *trigonal trisoctahedron*. Comparing it with the octahedron, Fig. 2, it will be seen that three of its planes correspond to one of the octahedron. The same is true also of the trapezohedron.

Fig. 6 is a *tetrahexahedron*, that is, a 4×6-faced solid, the faces being 24 in number, and four corresponding to each face of the cube or hexahedron (Fig. 1).

Fig. 7 is a hexoctahedron, that is, a 6×8-faced solid, a pyramid of six planes corresponding to each face in the octahedron, as is apparent on comparison. There are different kinds of hexoctahedrons known among crystallized isometric species, as well as of the two preceding forms. In each case the difference is not in number or general arrangement of planes, but in the angles between the planes, as explained beyond.

But these simple forms very commonly occur in combination with one another; a cube with the planes of an octahedron and the reverse, or with the planes of any or all of the other kinds above figured, and many others besides. Moreover, all stages between the different forms are often represented among the crystals of a species. Thus between the cube and octahedron occur the forms shown in Figs. 8 to 11. Fig. 12 is a cube; Fig. 8 represents the cube with a plane on each angle, equally inclined to each cubic face; 9, the same, with the planes on the angles more enlarged and

the cubic faces reduced in size; and then 10, the octahedron, with the cubic faces quite small; and Fig. 11, the octahedron, the cubic faces having disappeared altogether. This transformation is easily performed by the student with cubes cut out of chalk, clay, or a potato. It shows the fact



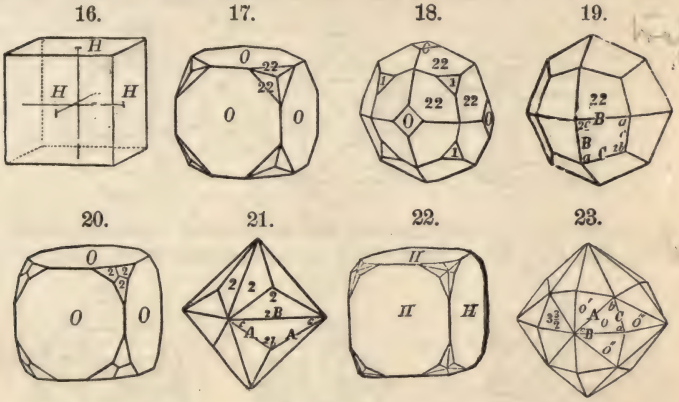
that the cubic axes (Fig. 12) connect the apices of the solid angles in the octahedron.

Again, between a cube and a dodecahedron there occur forms like Figs. 13 and 14; Fig. 12 being a cube, Fig. 13 the same, with planes *truncating* the edges, each plane being equally inclined to the adjacent cubic faces, and Fig. 14 another, with these planes on the edges large and the cubic faces small; and then, when the cubic faces disappear by further enlargement of the planes on the edges, the form is a dodecahedron, Fig. 15. The student should prove this transformation by trial with chalk or some other material, and so for other cases mentioned beyond. The surface of such models in chalk may be made hard by a coat of mucilage or varnish.

Again, between a cube and a trapezohedron there are the forms 17 and 18; 16 being the cube; 16, cube with three planes placed symmetrically on each angle; 18, the same with the cubic faces greatly reduced (but also with small octahedral faces), and 19, the trapezohedron, the cubic faces having disappeared.

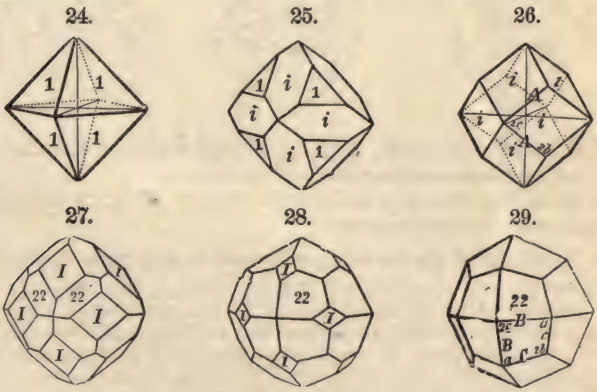
Again, Fig. 20 represents a cube with three planes on each

angle, which, if enlarged to the obliteration of the faces of the cube, become the trigonal trisoctahedron, Fig. 21. So



again, Fig. 22 represents a cube with six faces on each angle, which, if enlarged to the same extent as in the last, would become the hexoctahedron, Fig. 23.

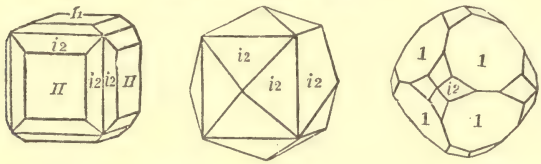
Again, Fig. 25 is a form between the octahedron (Fig. 24)



and dodecahedron (Fig. 26); and Figs. 27 and 28 are forms between the dodecahedron, Fig. 26, and trapezohedron, Fig. 29.

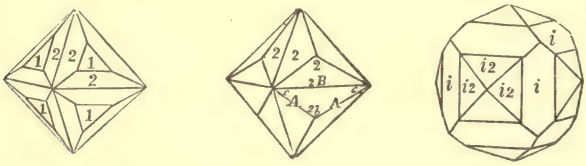
Again, Fig. 30 is a form between a cube (Fig. 16) and a tetrahexahedron, Fig. 31; Fig. 32, a form between an octahedron, Fig. 24, and a tetrahexahedron, Fig. 31; Fig. 33, a

30. 31. 32.



form between an octahedron and a trigonal trisoctahedron, Fig. 34; Fig. 35, a form between a dodecahedron (planes i)

33. 34. 35.



36. 37. 38.

and a tetrahexahedron; Fig. 36, a form between the dodecahedron and a hexoctahedron, Fig. 37.

Fig. 38 represents a cube with planes of both the octahedron and dodecahedron.

2. Positions of planes with reference to the axes. Lettering of figures.—The numbers by which the planes in the above figures, and others of the work, are lettered, indicate the positions of the planes with reference to the axes, and exhibit the mathematical symmetry and ratios in crystallization. In the figure of the cube (Fig. 1) the three axes are represented; the lateral semi-axis which meets the front planes in the figure is lettered a; that meeting the side plane to the right b, and the vertical axis c, and the other halves of the same axes respectively $-a$, $-b$, $-c$. By a study of the positions of the planes of the cube and other forms with reference to these axes, the following facts will become apparent.

In the cube (Fig. 1) the front plane touches the extremity of axis *a*, but is parallel to axes *b* and *c*. When one line or plane is parallel to another they do not meet except at an infinite distance, and hence the sign for infinity is used to express parallelism. Employing *i*, the initial of infinity, as this sign, and writing *c*, *b*, *a*, for the semi-axes so lettered, then the position of this plane of the cube is indicated by the expression $ic : ib : 1a$. The top and side-planes of the cube meet one axis and are parallel to the other two, and the same expression answers for each, if only the letters *a*, *b*, *c*, be changed to correspond with their positions. The opposite planes have the same expressions, except that the *c*, *b*, *a*, will refer to the opposite halves of the axes and be *-c*, *-b*, *-a*.

In the dodecahedron, Fig. 15, the right of the two vertical front planes *i* meets two axes, the axes *a* and *b*, at their extremities, and is parallel to the axis *c*. Hence the position of this plane is expressed by $ic : 1b : 1a$. So, all the planes meet two axes similarly and are parallel to the third. The expression answers as well for the planes *i* in Figs. 13, 14, as for that of the dodecahedron, for the planes have all the same relation to the axes.

In the octahedron, Fig. 11, the face 1 situated to the right above, like all the rest, meets the axes *a*, *b*, *c*, at their extremities; so that the expression $1c : 1b : 1a$ answers for all.

Again, in Fig. 17 (p. 21) there are three planes, 2-2, placed symmetrically on each angle of a cube, and, as has been illustrated, these are the planes of the trapezohedron, Fig. 19. The upper one of the planes 2-2 in these figures, when extended to meet the axes (as in Fig. 19), intersects the vertical *c* at its extremity, and the others, *a* and *b*, at twice their lengths from the centre. Hence the expression for the plane is $1c : 2b : 2a$. So, as will be found, the left-hand plane 2-2 on Fig. 17, will have the expression $2c : 1b : 2a$; and the right-hand one, $2c : 2b : 1a$. Further, the same ratio, by a change of the letters for the semi-axes, will answer for all the planes of the trapezohedron.

In Fig. 20 there are other three planes, 2, on each of the angles of a cube, and these are the planes of the trisoctahedron in Fig. 21. The lower one of the three on the upper front solid angle, would meet if extended, the extremities of the axes *a* and *b*, while it would meet the vertical axis at *twice* its length from the centre. The expression $2c : 1b : 1a$ indicates, therefore, the position of the plane. So also, $1c : 1b : 2a$ and $1c : 2b : 1a$ represent the positions of the other two planes adjoining; and corresponding expressions may be similarly obtained for all the planes of the trisoctahedron.

Again, in Fig. 30, of the cube with two planes on each edge, and in Fig. 31, of the tetrahexahedron bounded by these same planes, the left of the two planes on the front vertical edge of Fig. 30 (or the corresponding plane on Fig. 31) is parallel to the vertical axis; its intersections with the lateral axes, *a* and *b*, are at unequal distances from the centre, expressed by the ratio $2b : 1a$. This ratio for the plane adjoining on the right is $1b : 2a$. The position of the former is expressed by the ratio $ic : 2b : 1a$, and for the other by $c : 1b : 2a$. Thus, for each of the planes of this tetrahexahedron the ratio between two axes is 1 : 2, while the plane is parallel to the third axis.

Again, in Fig. 22, of the cube with six planes on each solid angle, and in the hexoctahedron in Fig. 23, made up of such planes, each of the planes when extended so that it will meet one axis at once its

length from the centre, will meet the other axes at distances expressed by a constant ratio, and the expression for the lower right one of the six planes will be $3c : \frac{3}{2}b : 1a$. By a little study, the expressions for the other five adjoining planes can be obtained, and so also those for all the 48 planes of the solid.

In the isometric system the axes, *a*, *b*, *c*, are equal, so that in the general expressions for the planes these letters may be omitted; the expressions for the above-mentioned forms thus become—

Cube (Fig. 1), $i : 1 : i$.	Tetrahexahedron (Fig. 5), $i : 1 : 2$.
Octahedron (Fig. 2), $1 : 1 : 1$.	Trigonal trisoctahedron (Fig. 6), $2 : 1 : 1$.
Dodecahedron (Fig. 3), $1 : 1 : i$.	
Trapezohedron (Fig. 4), $2 : 1 : 2$.	Hexoctahedron (Fig. 7), $3 : 1 : \frac{3}{2}$.

Looking again at Fig. 17, representing the cube with planes of the trapezohedron, $2 : 1 : 2$, it will be perceived that there might be a trapezohedron having the ratios $1\frac{1}{2} : 1 : 1\frac{1}{2}$, $3 : 1 : 3$, $4 : 1 : 4$, $5 : 1 : 5$, and others; and, in fact, such trapezohedrons occur among crystals. So also, besides the trigonal trisoctahedron $2 : 1 : 1$ (Fig. 21), there might be, and there in fact is, another corresponding to the expression $3 : 1 : 1$; and still others are possible. And besides the hexoctahedron $3 : 1 : \frac{3}{2}$ (Fig. 23), there are others having the ratios $4 : 1 : 2$, $4 : 1 : \frac{4}{3}$, $5 : 1 : \frac{5}{3}$, and so on.

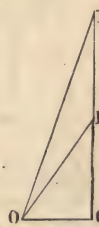
In the above ratios, the number for one of the lateral axes is always made a unit, since only a ratio is expressed; omitting this in the expression, the above general ratios become: for the cube, $i : i$; for the octahedron, $1 : 1$; dodecahedron, $1 : i$; trapezohedron, $2 : 2$; tetrahexahedron, $i : 2$; trigonal-trisoctahedron, $2 : 1$; and hexoctahedron, $3 : \frac{3}{2}$. In the lettering of the figures these ratios are put on the planes, but with the second figure, or *that referring to the vertical* axis, first. Thus the lettering on the hexoctahedron (Fig. 23), is $3\text{-}\frac{3}{2}$; on the trigonal trisoctahedron (Fig. 21) is 2, the figure 1 being unnecessary; on the tetrahexahedron (Fig. 31), *i*-2; on the trapezohedron (Figs. 4 and 19), 2-2; on the dodecahedron (Fig. 15), *i*; on the octahedron, 1; on the cube, *i*-*i*, in place of which *H* is used, the initial of hexahedron. In the printed page these symbols are written with a hyphen in order to avoid occasional ambiguity, thus $3\text{-}\frac{3}{2}$, *i*-2, 2-2, etc. Similarly, the ratios for all planes, whatever they are, may be written. The numbers are usually small, and never decimal fractions.

The angle between the planes *i*-2 (or $i : 1 : 2$) and *H*, in Fig. 30, page 22, may be easily calculated, and the same for any plane of the series *i*-*n* ($i : 1 : n$). Draw the right-angled triangle, *ADC*, as in the annexed figure, making the vertical side, *CD*, twice that of *AC*, the base; that is, give them the same ratio as in the axial ratio for the plane. If $AC = 1$, $CD = 2$. Then, by trigonometry, making *AC* the radius, $1 : R :: 2 : \tan DAC$; or $1 : R :: 2 : \cot ADC$. Whence $\tan DAC = \cot ADC = 2$. By adding to 90°, the angle of the triangle obtained by working the equation, we have the inclination of the basal plane *H*, on the plane *i*-2. So in all cases, whatever the value of *n* that value equals the tangent of the basal angle of the triangle (or the cotangent of the angle at the vertex), and from this the inclination to the cubic faces is

directly obtained by adding 90°. If $n = 1$, then the ratio is 1 : 1, as in ACB, and each angle equals 45°, giving 135° for the inclination on either adjoining cubic face.

Again if the angles of inclination have been obtained by measurement, the value of n in any case may be found by reversing the above calculation; subtracting 90° from the angle, then the tangent of this angle, or the cotangent of its supplement, will equal n, the tangents varying directly with the value of n.

In the case of planes of the $m : 1 : 1$ series (including 1 : 1 : 1, 2 : 1 : 1, etc.), the tangents of the angle between a cubic face in the same zone and these planes, less 90°, varies with the value of m. In the case of the plane 1 (or 1 : 1 : 1), the angle between it and the cubic face is 125° 16′. Substracting 90°, we have 35° 16′. Draw a right-angled triangle, OBC, with 35° 16′ as its vertex angle. BC has the value of 1c, or the semi-axis of the cube. Make $DC = 2BC$. Then, while the angle OBC has the value of the inclination on the cubic face less 90° for the plane 1 : 1 : 1, ODC has the same for the plane 2 : 1 : 1. Now, making OC the radius, and taking it as unity, BC is the tangent of BOC, or *cot* OBC. So $DC = 2BC$ is the tangent of DOC, or *cot* ODC. By lengthening the side CD ($= 2BC$ or 2c) it may be made equal to $3BC = 3c$, its value in the case of the plane 3 : 1 : 1 ; or to $4BC = 4c$, its value in the case of the plane 4 : 1 : 1 ; or $mBC = mc$ for any plane in the series $m : 1 : 1$; and since in all there will be the same relation between the vertical and the tangent of the angle at the base (or the cotangent of the angle at the vertex), it follows that the tangent varies with the value of m. Hence, knowing the value of the angle in the case of the form 1 (1 : 1 : 1), the others are easily calculated from it.



BC being a unit, the actual value of OC is $\frac{1}{2}\sqrt{2}$, or $\sqrt{\frac{1}{2}}$, it being half the diagonal of a square, the sides of which are 1, and from this value the angle 35° 16′ might be obtained for the angle OBC.

The above law (that, for a plane of the $m : 1 : 1$ series, the tangent of its inclination on a cubic face lying in the same zone, less 90°, varies with the value of m, and that it may be calculated for any plane $m : 1 : 1$ from this inclination in the form 1 : 1 : 1), holds also for planes in the series $m : 2 : 1$, or $m : 3 : 1$, or any $m : n : 1$. That is, given the inclination of O on $1 : n : 1$, its tangent doubled will be that of $2 : n : 1$, or trebled, that of $3 : n : 1$, and so on ; or halved, it will be that of the plane $\frac{1}{2} : n : 1$, which expression is essentially the same as $1 : 2n : 2$.

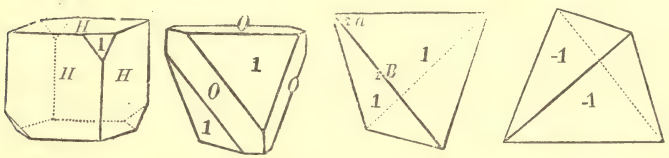
These examples show some of the simpler methods of applying mathematics in calculations under the isometric system. The values of the axes are not required in them, because $a = b = c = 1$.

3. Hemihedral Crystals.—The forms of crystals described above are called *holohedral* forms, from the Greek for *all* and *face*, the number of planes being all that full symmetry requires. The cube has eight *similar* solid angles—*similar, that is, in the enclosing planes and plane angles.* Con-

sequently the law of full symmetry requires that all should have the same planes and the same number of planes; and this is the general law for all the forms. This is a consequence of the equality of the axes and their rectangular intersections.

But in some crystalline forms there are only *half* the number of planes which full symmetry requires. In Fig. 39 a cube is represented with an octahedral plane on half, that is, four, of the solid angles. A solid angle having such

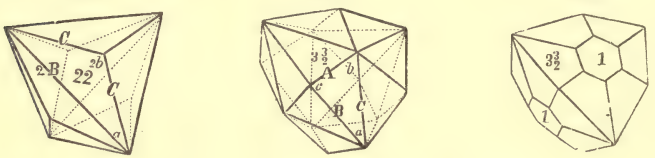
40. 41. 42.



a plane is diagonally opposite to one without it. The same form is represented in Fig. 40, only the cubic faces are the smallest; and in Fig. 41 the simple form is shown which is made up of the four octahedral planes. It is a *tetrahedron* or regular three-sided pyramid. If the octahedral faces of Fig. 39 had been on the other four of the solid angles of the cube, the tetrahedron made of those planes would have been that of Fig. 42 instead of Fig. 41.

Other hemihedral forms are represented in Figs. 43 to 45. Fig. 43 is a hemihedral form of the trapezohedron, Fig.

43. 44. 45.



4, p. 18; Fig. 44, hemihedral of the hexoctahedron, Fig. 7, or a hemi-hexoctahedron; and Fig. 45 is a combination of the tetrahedron (plane 1) and hemi-hexoctahedron.

In these forms Figs. 41–44, no face has another parallel to it; and consequently they are called *inclined hemihedrons*.

Fig. 46 represents a cube with the planes of a tetrahexa-

hedron, as already explained. In fig. 47, the cube has *only one* of the planes i-2 on each edge, and therefore only twelve in all; and hence it affords an example of hemihedrism—a kind that is presented by many crystals of pyrite.

46. 47. 48. 49.

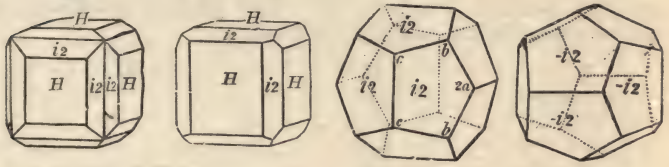
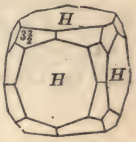


Fig. 48 is the hemihedral form resulting when these twelve planes i-2 are extended to the obliteration of the cubic faces; and Fig. 49 is another, made of the other twelve of these planes. Again, in Fig. 50, a cube is represented having only three out of the six planes of Fig. 22, and this is another example of hemihedrism. These kinds differ from the *inclined* hemihedrons in having *opposite parallel faces*, and hence they are called *parallel hemihedrons*.

50.



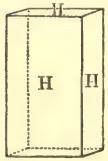
4. Internal Structure of Isometric Crystals, or Cleavage.—The crystals of many isometric minerals have *cleavage*, or a greater or less capability of division in directions situated symmetrically with reference to the axes. The cleavage directions are parallel either to the faces of the cube, the octahedron, or the dodecahedron. In galenite (p. 160) there is *easy* cleavage in three directions parallel to the faces of the cube; in fluorite (p. 227), in four directions parallel to the faces of the octahedron; in sphalerite (p. 170), in six directions parallel to the faces of the dodecahedron. These cleavages are an important means of distinguishing the species.

The three cubic cleavages are precisely alike in the ease with which cleavage takes place, and in the kinds of surface obtained; and so is it with the four in the octahedral directions, and the six in the dodecahedral. Occasionally cleavages of two of these systems occur in the same mineral; that is, for example, parallel both to the faces of the cube and of the octahedron; but when so, those of one system are

much more distinct than those of the other, and cleavage surfaces in the two directions are quite unlike as to smoothness and lustre.

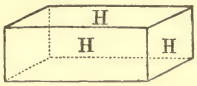
5. Irregularities of Isometric Crystals.—A cube has its faces precisely equal, and so it is with each of the forms represented in Figs. 2 to 7, p. 18. This perfect symmetry is almost never found in actual crystals.

51.



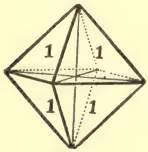
52.

53.



A cubic crystal has generally the form of a square prism (Fig. 51 a stout one, Fig. 52 another long and slender), or a rectangular prism (Fig. 53). In such cases the crystal may still be known to be a cube; because, if so, the kind of sur-

54.



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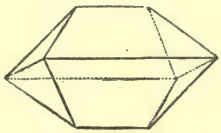

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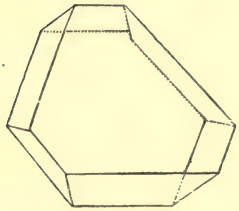

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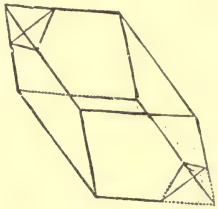
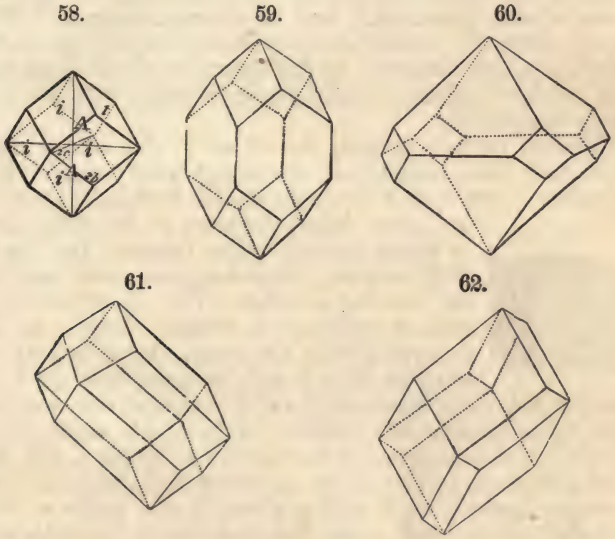


face and kind of lustre on the six faces will be precisely alike; and if there is cubic cleavage it will be exactly equal in facility in three rectangular directions; or if there is cleavage in four, or six, directions, it will be equal in

degree in the four, or the six, directions, and have mutual inclinations corresponding with the angles of the octahedron or dodecahedron; and thus the crystal will show that it is isometric in system.

The same shortening or lengthening of the crystal often disguises greatly the octahedron, dodecahedron, and other forms. This is illustrated in the following figures: Fig. 54 shows the form of the regular octahedron; 55, an octahedron lengthened horizontally; 56, one shortened parallel to one of the pairs of faces; 57, one lengthened parallel to another pair, the ultimate result of which obliterates two of the faces, and places an acute solid angle in place of each. The solid is then six-sided, and has rhombic faces whose plane angles are 120° and 60°. The following figures



illustrate corresponding changes in the dodecahedron (Fig. 58). In Fig. 59 the dodecahedron is lengthened vertically, making a square prism with four-sided pyramidal terminations. In 60, it is shortened vertically. In 61 the dodecahedron is lengthened obliquely in the direction of an octahedral axis, and in 62 it is shortened in the same direction, making six-sided prisms with trihedral terminations.

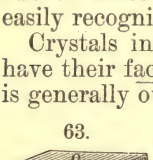
So again in the trapezohedron there are equally deceptive forms arising from elongations and shortenings in the same two directions.

These distortions change the relative sizes of planes, but not the values of angles. In crystals of the several forms represented in Figs. 54 to 57, the inclinations are the same as in the regular octahedron. There is the same constancy of angle in other distorted crystals.

Occasionally, as in the diamond, the planes of crystals are convex; and then, of course, the angles will differ from the true angle. It is important, in order to meet the difficulties in the way of recognizing isometric crystals, to have clearly in the mind the precise aspect of an equilateral triangle, which is the shape of a face of an octahedron; the form of the rhombic face of the dodecahedron; and the form of the trapezoidal face of a trapezohedron. With these distinctly remembered, isometric crystalline forms that are much obscured by distortion, or which show only two or three planes of the whole number, will often be easily recognized.

Crystals in this system, as well as in the others, often have their faces striated, or else rough with points. This is generally owing to a tendency in the forming crystal to make two different planes at the same time, or rather an oscillation between the condition necessary for making one plane and that for making another. Fig. 63 represents a cube of pyrite with striated faces. As the faces of a cube are equal, the striations are alike on all. It will be noted that the striations of adjoining faces are at right angles to one another. The little ridges of the striated surfaces are made up of planes of the pentagonal dodecahedron (Fig. 49, p. 27), and they arise from an oscillation in the crystallizing conditions between that which, if acting alone, would make a cube, and that which would make this hemihedral dodecahedron. Again, in magnetite, oscillations between the octahedron and dodecahedron produce the striations in Fig. 64.

63.

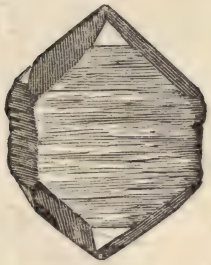


Octahedral crystals of fluorite often occur with the faces made up of evenly projecting solid angles of a cube, giving them rough instead of polished planes. This has arisen from oscillation between octahedral and cubic conditions.

In some cases crystals are filled out only along the diago-

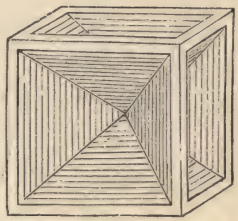
nal planes. Fig. 65 represents a crystal of common salt of this kind, having pyramidal depressions in place of the regular faces. Octahedrons of gold sometimes occur with

64.



MAGNETITE.

65.



COMMON SALT.

three-sided pyramidal depressions in place of the octahedral faces. Such forms sometimes result also when crystals are eroded by any cause.

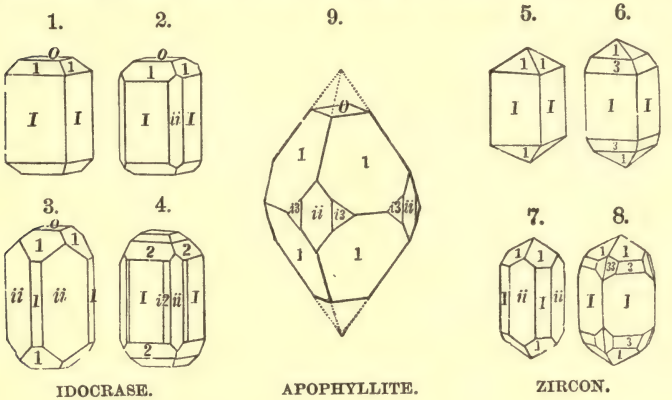
II. TETRAGONAL SYSTEM.

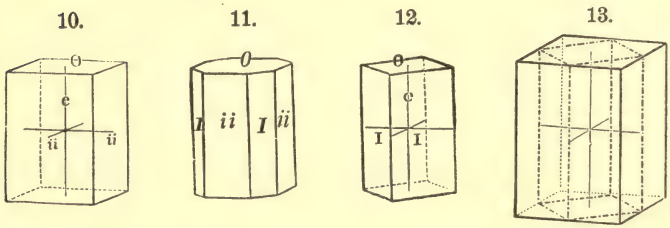
1. Descriptions of Forms.—In this system (1) the axes cross at right angles; (2) the vertical axis is either longer or shorter than the lateral; and (3) the lateral axes are equal.

The following figures represent some of the crystalline forms. They are very often attached by one extremity to the supporting rock and have perfect terminating planes only at the other. Square prisms, with or without pyramidal terminations, square octahedrons, eight-sided prisms, eight-sided pyramids, and especially combinations of these, are the common forms. Since the lateral axes are equal, the four lateral planes of the square prisms are alike in lustre and surface-markings. For the same reason the symmetry of the crystal is throughout by fours; that is, the number of similar pyramidal planes at the extremity is either four or eight; and they show that they are similar by being exactly alike in inclination to the basal plane as well as alike in lustre.

There are two distinct square prisms. In one (Fig. 10) the axes connect the centres of the lateral faces. In the

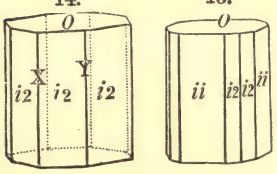
other (Fig. 12) they connect the centres of the lateral edges. In Fig. 11 the two prisms are combined; the figure shows that the planes of one truncate the lateral edges of the





other, the interfacial angle between adjoining planes being 135°. Figs. 2, 3, 4, 7, are of others having planes of both prisms. In Fig. 13 one prism is represented within the other.

Fig. 14 represents an eight-sided prism, and Fig. 15 a combination of a square prism (i-i) with an eight-sided prism (i-2). Another example of this is shown in Fig. 4, and also in Fig. 9, the planes i-2 in one, and i-3 in the other.

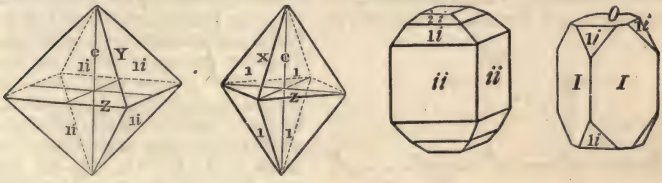


The basal plane in these prisms is an independent plane, because the vertical axis is not equal to the

lateral, and hence it almost always differs in lustre and smoothness from the lateral.

Like the square prisms, the square octahedrons are in two series, one set (Fig. 16) having the lateral or basal edges parallel to the lateral axes, and these axes connecting the centres of opposite basal edges, and the other (Fig. 17) having them diagonal to the axes, these axes connecting the apices of the opposite solid angles, as in the isometric octahedron. There may be, on the same crystal, faces of several octahedrons of these two series, differing in having their planes inclined at different angles to the basal plane.

16. 17. 18. 19.



In Figs. 5 and 7 planes of one of these pyramids terminate the prism, and in Figs. 6 and 8 the planes of two. In Figs. 1 to 3 there are planes of the same octahedron, but combined with the basal plane *O*; and in Fig. 4 there are planes of two, with *O*. In Fig. 9 there are planes of the same octahedron, with planes of a square prism (*i*-*i*), and of an eight-sided prism (*i*-2). In Fig. 18 there is the prism *i*-*i* combined with two octahedrons, and the basal plane *O*; and in 19 the planes of one octahedron with the prism *I*.

Fig. 20 represents an eight-sided double pyramid, made

20. 21. 22.

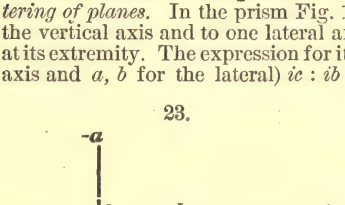
of equal planes, equally inclined to the base; and Fig. 21, the same planes on the square prism *i*-*i*. The small planes,

in pairs, on Fig. 8, are of this kind. In Fig. 22 the small planes 3-3 of Fig. 8 occur alone, without planes of the four-sided pyramids, and therefore make the eight-sided pyramid, 3-3.

The solid made of two such eight-sided pyramids placed base to base has the largest number of similar planes possible in the tetragonal system, while the largest number in the isometric system (occurring in the hexoctahedron) is forty-eight.

2. Positions of the planes with reference to the Axes.—*Lettering of planes.* In the prism Fig. 10, the lateral planes are parallel to the vertical axis and to one lateral axis, and meet the other lateral axis at its extremity. The expression for it is hence (*c* standing for the vertical axis and *a*, *b* for the lateral) $ic : ib : 1a$, *i*, as before, standing for infinity and indicating parallelism.

23.



For the prism of Fig. 12, the prismatic planes meet the two lateral axes at their extremities, and are parallel to the vertical, and hence the expression for them is $ic : 1b : 1a$. In the annexed figure the two bisecting lines, *a* -*a* and *b* -*b*, represent the lateral axes; the line *st* stands for a section of a lateral plane of the first of these prisms, it being parallel to one lateral axis and meeting the other at its extremity, and *ab* for that of the second, it meeting the two at their extremities.

In the eight-sided prisms (Figs. 14, 15), each of the lateral planes is parallel to the vertical axis, meets one of the lateral axes at its extremity, and would meet the other axis if it were prolonged to two or three or more times its length. The line *ao*, in Fig. 23, has the position of one of the eight planes; it meets the axis *b* at *o*, or twice its length from the centre; and hence the expression for it would be $ic : 2b : 1a$, or, since $b = a$, $ic : 2 : 1$, which is a general expression for each of the eight planes. Again, *ap* has the position of one of the eight planes of another such prism; and since *Op* is three times the length of *Ob*, the expression for the plane would be $ic : 3 : 1$. So there may be other eight-sided prisms; and, putting *n* for any possible ratio, the expression $ic : n : 1$ is a general one for all eight-sided prisms in the tetragonal system.

A plane of the octahedron of Fig. 16 meets one lateral axis at its extremity, and is parallel to the other, and it meets the vertical axis *c* at its extremity; its expression is consequently (dropping the letters *a* and *b*, because these axes are equal) $1c : i : 1$. Other octahedrons in the same vertical series may have the vertical axis longer or shorter than axis *c*; that is, there may be the planes $2c : i : 1$, $3c : i : 1$, $4c : i : 1$, and so on; or $\frac{1}{2}c : i : 1$, $\frac{1}{4}c : i : 1$, and so on; or, using *m* for any coefficient of *c*, the expression becomes general, $mc : i : 1$. When $m = 0$ the vertical axis is zero, and the plane is the basal plane *O* of the

prism; and when m = infinity, the plane is $ic : i : 1$, or the vertical plane of the prism in the same series, *i-i*, Fig. 10.

The planes of the octahedron of Fig. 17 meet two lateral axes at their extremities, and the vertical at its extremity, and the expression for the plane is hence $1c : 1 : 1$. Other octahedrons in this series will have the general expression $mc : 1 : 1$, in which m may have any value, not a decimal, greater or less than unity, as in the preceding case. When in this series m = infinity, the plane is that of the prism $ic : 1 : 1$, or that of Fig. 12.

In the case of the double eight-sided pyramid (Figs. 20, 21, 22), the planes meet the two lateral axes at *unequal* distances from the centre; and also meet the vertical axis. The expression may be $2c : 2 : 1$, $4c : 2 : 1$, $5c : 3 : 1$, and so on; or, giving it a general form, $mc : n : 1$.

In the lettering of the planes on figures of tetragonal crystals, the first number (as in the isometric and all the other systems) is the coefficient of the vertical axis, and the other is the ratio of the other two, and when this ratio is a unit it is omitted.

The expressions and the lettering for the planes are then as follows:

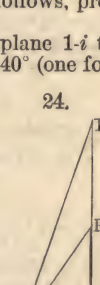
		Expressions.	Lettering.
For square prisms	1.	$ic : i : 1$	*i-i*
	2.	$ic : 1 : 1$	*i* or *I*.
For eight-sided prisms		$ic : n : 1$	*i-n*
For octahedrons	1.	$mc : i : 1$	*m-i*
	2.	$mc : 1 : 1$	*m*
For double eight-sided pyramids,		$mc : n : 1$	*m-n*

The symbols are written without a hyphen on the figures of crystals. On Fig. 14, the plane *i-n* is that particular *i-n* in which $n = 2$, or *i*-2. In Fig. 21 the planes of the double eight-sided pyramid, *m-n*, have $m = 1$ and $n = 2$ (the expression being $1 : 2 : 1$), and hence it is lettered 1-2. In Fig. 8 and in Fig. 22 it is the one in which $m = 3$ and $n = 3$ (the expression being $3 : 3 : 1$), and hence the lettering 3-3.

The length of the vertical axis c may be calculated as follows, provided the crystal affords the required angles:

Suppose, in the form Fig. 18, the inclination of O on plane 1-*i* to have been found to be 130°, or of *i-i* on the same plane, 140° (one follows from the other, since the sum of the two, as has been explained, is necessarily 270°). Subtracting 90°, we have 40° for the inclination of the plane on the vertical axis c, or 50° for the same on the lateral axis a, or the basal section. In the right-angled triangle, OBC, the angle OBC equals 40°. If OC be taken as $a = 1$, then BC will be the length of the vertical axis c; and its value may be obtained by the equation cot 40° = BC, or tan 50° = BC.

24.



On Fig. 18 there is a second octahedral plane, lettered $\frac{1}{2}$-*i*, and it might be asked, Why make this plane $\frac{1}{2}$-*i*, instead of 1-*i*? The determination on this point is more or less arbitrary. It is usual to *assume* that plane as the unit plane in one or the other series of octahedrons (Fig. 16 or Fig. 17) which is of most common occurrence, or that which will give the simplest symbols to the crystalline

forms of a species; or that which will make the vertical axis nearest to unity; or that which corresponds to a cleavage direction.

The value of the vertical axis having been thus determined from 1-*i*, the same may be determined in like manner for $\frac{1}{2}$-*i* in the same figure (Fig. 18). The result would be a value just half that of *BC*. Or if there were a plane 2-*i*, the value obtained would be twice *BC*, or *BD* in Fig. 24; the angle $ODC + 90°$ would equal the inclination of *O* on 2-*i*. So for other planes in the same vertical zone, as 3-*i*, 4-*i*, or any plane *m*-*i*.

If there were present several planes of the series *m*-*i*, and their inclinations to the basal plane *O* were known, then, after subtracting from the values 90°, the cotangents of the angles obtained, or the tangents of their complements, will equal *m* in each case; that is, the tangents (or cotangents) will vary directly with the value of *m*. The logarithm of the tangent for the plane 1-*i*, added to the logarithm of 2, will equal the logarithm of the tangent for the plane 2-*i*, and so on.

The *law of the tangents* for this vertical zone *m*-*i* holds for the planes of all possible vertical zones in the tetragonal system. Further, if the square prism were laid on its side so that one of the lateral planes became the base, and if zones of planes are present on it that are vertical with reference to this assumed base, the law of the tangents still holds, with only this difference to be noted, that then one of the lateral axes is the vertical. It holds also for the *orthorhombic* system, no matter which of the diametral planes is taken for the base, since all the axial intersections are rectangular. It holds for the *monoclinic* system for the zone of planes that lies between the axes *c* and *b* and that between the axes *a* and *b*, since these axes meet at right angles, but not for that between *c* and *a*, the angle of intersection here being oblique. It holds for all vertical zones in the *hexagonal* system, since the basal plane in this system is at right angles to the vertical axis. But it is of no use in the *triclinic* system, in which all the axial intersections are oblique.

The value of the vertical axis *c* may be calculated also from the inclination of *O* on 1, or of *I* on 1. See Fig. 2, and compare it with Fig. 17. If the angle *I* on 1 equals 140°, then, after subtracting 90°, we have 50° for the basal angle in the triangle *OCB*, Fig. 24; or for half the interfacial angle over a basal edge—edge *Z*—in Fig. 17. The value of *c* may then be calculated by means of the formula

$$c = \tan \tfrac{1}{2}Z \sqrt{\tfrac{1}{2}},$$

by substituting 50° for $\frac{1}{2}Z$ and working the equation.

For any octahedron in the series *m*, the formula is

$$mc = \tan \tfrac{1}{2}Z \sqrt{\tfrac{1}{2}}$$

Z being the angle over the basal edge of that octahedron. If $m = 2$, then $c = \frac{1}{2}(\tan \frac{1}{2}Z \sqrt{\frac{1}{2}})$. Further, $m = (\tan \frac{1}{2}Z \sqrt{\frac{1}{2}}) \div c$.

The interfacial angle over the terminal edge of any octahedron *m* may be obtained, if the value of *c* is known, by the formulas

$$mc = \cot \varepsilon \qquad \cos \varepsilon = \cot \tfrac{1}{2}X$$

X being the desired angle (Fig. 17). The same for any octahedron *m*-*i* may be calculated from the formulas

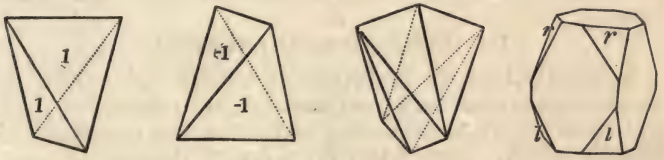
$$mc = \cot \varepsilon \qquad \cos \varepsilon = \cos \tfrac{1}{2} Y \sqrt{2}$$

Y being the desired angle (Fig. 16).

For other methods of calculation reference may be made to the "Text-book of Mineralogy," or to some other work treating of mathematical crystallography.

3. Hemihedral Forms.—Among the hemihedral forms under the tetragonal system there is a tetrahedron, called a sphenoid (Fig. 25 or 26), and also forms in which only half of the sixteen planes of the double eight-sided pyramid, or half the eight planes of an eight-sided prism—those alter-

25. 26. 27. 28.



nate in position—are present (Figs. 27, 28). In Fig. 27 the absent planes are those of half the *pairs* of planes; and in Fig. 28 they include one of each of the pairs, as will be seen on comparing these figures with Fig. 21.

4. Cleavage.—In this system cleavage may occur parallel to the sides of either of the square prisms; parallel to the basal plane; parallel to the faces of a square octahedron; or in two of these directions at the same time. Cleavage parallel to the base and that parallel to a prism are never equal, so that such prisms need not be confounded with distorted cubes.

5. Irregularities in Crystals.—The square prisms are very often rectangular instead of square, and so with the octahedrons. But, as elsewhere among crystals, the angles remain constant. When forms are thus distorted, the four prismatic planes will have like lustre and surface markings, and thus show that the faces are normally equal and the lateral axes therefore equal. If the plane truncating the edge of a prism makes an angle of precisely 135° with the faces of the prism, this is proof that the prism is square, or that the lateral axes are equal, since the angle between a diagonal of a square and one of its sides is 45°, and 135° is the supplement of 45°.

6. Distinctions.—The tetragonal prisms have the base

different in lustre from the sides, and planes on the basal edges different in angle from those on the lateral, and thus they differ from isometric forms. The lateral edges may be truncated, and the new plane will have an angle of 135° with those of the prism, in which they differ from orthorhombic forms, while like isometric. The extremities of the prism, if it have any planes besides the basal, will have them in fours or eights, each of the four, or of the eight, inclined to the base at the same angle. When there is any cleavage parallel to the vertical axis, it is alike in two directions at right angles with one another. The lateral planes of either square prism are alike in lustre and markings.

III. ORTHORHOMBIC SYSTEM.

1. Descriptions of Forms.—The crystals under the orthorhombic system vary from rectangular to rhombic prisms and rhombic octahedrons, and include various combinations of such forms. Figs. 1 to 7 are a few of those of the species barite, and Figs. 8 to 10 of crystals of sulphur.

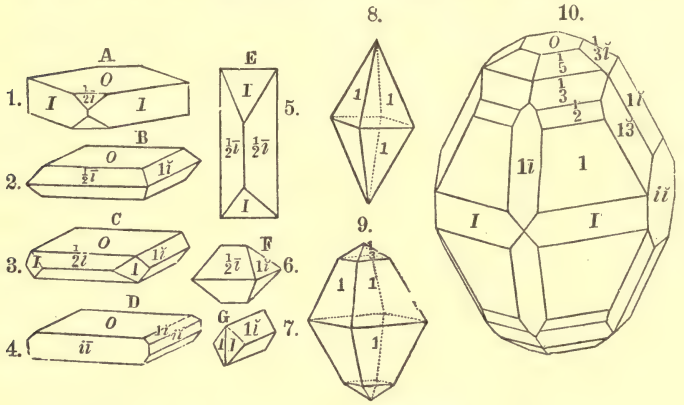


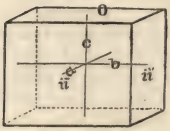
Fig. 11 represents a rectangular prism (diametral prism), and Fig. 12 a rhombic prism, each with the axes. The axes connect the centres of the opposite planes in the former; but in the latter the lateral axes connect the centres of the opposite edges. Of the two lateral axes the longer is called the *macrodiagonal,* and the shorter the *brachydi-*

agonal. The vertical section containing the former is the *macrodiagonal section*, and that containing the latter, the *brachydiagonal section.*

In the rectangular prism, Fig. 11, only opposite planes are alike, because the three axes are unequal. Of these planes, that opposite to the larger lateral axis is called the *macropinacoid*, and that opposite the shorter the *brachypinacoid* (from the Greek for long and short, and a word signifying *board* or *table*). Each pair—that is, one of these planes and its opposite—is called a hemiprism.

In the rhombic prism, Fig. 12, the four lateral planes are similar planes. But of the four lateral edges of the

11.



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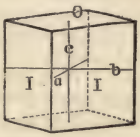

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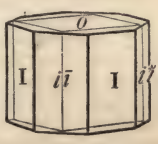


prism two are obtuse and two acute. Fig. 13 represents a combination of the rectangular and rhombic prisms, and illustrates the relations of their planes. Other rhombic prisms parallel to the vertical axis occur, differing in interfacial angles, that is, in the ratio of the lateral axes.

Besides *vertical* rhombic prisms, there are also horizontal prisms parallel to each lateral axis, *a* and *b*. In Fig. 2 the narrow planes in front (lettered $\frac{1}{2}\breve{1}$) are planes of a rhombic prism parallel to the *longer* of the lateral axes, and those to the right ($1\breve{1}$) are planes of another parallel to the shorter lateral axis. In Fig. 6 the planes are those of these two horizontal prisms. Such prisms are called also *domes*, because they have the form of the roof of a house (*domus* in Latin meaning *house*). In Fig. 3 these same two domes occur, and also the planes (lettered *I*) of a *vertical* rhombic prism. Of these domes there may be many, both in the macrodiagonal and the brachydiagonal series, differing in angle (or in ratio of the two intersected axes). Those parallel to the longer lateral axis, or the macrodiagonal, are called *macrodomes;* and those parallel to the shorter, or brachydiagonal, are called *brachydomes.*

A rhombic octahedron, lettered 1, is shown in Fig. 8; a combination of two, lettered 1 and $\frac{1}{3}$, in Fig. 9; and a com-

bination of four, lettered 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, in Fig. 10. This last figure contains also the planes *I*, or those of a vertical rhombic prism; the planes 1-$\breve{i}$, or those of a dome parallel to the *longer* lateral axis; the planes 1-$\breve{\imath}$, or those of a dome parallel to the *shorter* lateral axis; the plane *O*, or the basal plane; the plane *i*-$\breve{\imath}$, or the brachypinacoid; and also a rhombic octahedron lettered 1-$\breve{3}$.

2. Positions of Planes. Lettering of Crystals.—The notation is, in a general way, like that of the tetragonal system, but with differences made necessary by the inequality of the lateral axes. The letters for the three are written $\breve{c} : \bar{b} : \breve{a}$; $\bar{b}$ being the longer lateral and $\breve{a}$ the shorter lateral. In place of the square prism of the tetragonal system, *i*-$\bar{\imath}$, there are the hemiprisms *i*-$\bar{\imath}$ and *i*-$\bar{\imath}$, or the macropinacoid and brachypinacoid, having the expressions $\breve{c} : \breve{\imath}\bar{b} : 1\breve{a}$ and $\breve{c} : 1\bar{b} : \breve{\imath}\breve{a}$. The form *I* is the rhombic prism, having the expression $\breve{c} : 1\bar{b} : 1\breve{a}$, corresponding to the square prism *I* in the tetragonal system. The planes *i*-$\breve{n}$ or *i*-$\breve{n}$ are other rhombic vertical prisms, the former corresponding to $\breve{c} : n\bar{b} : 1\breve{a}$, the other to $\breve{c} : 1\bar{b} : n\breve{a}$. If $n = 2$, the plane is lettered either *i*-$\bar{2}$ or *i*-$\breve{2}$. The plane 1-$\breve{3}$ has the expression $1\breve{c} : 1\bar{b} : 3\breve{a}$. *m*-$\bar{n}$ and *m*-$\breve{n}$ comprise all possible rhombic prisms and octahedrons, and correspond to the expressions $m\breve{c} : n\bar{b} : 1\breve{a}$ and $m\breve{c} : 1\bar{b} : n\breve{a}$. When $m =$ infinity they become *i*-$\bar{n}$ and *i*-$\breve{n}$, or expressions for vertical rhombic prisms; when $n =$ infinity they become *m*-$\bar{\imath}$ and *m*-$\breve{\imath}$, or expressions for macrodomes and brachydomes.

The question which of the three axes should be taken as the vertical axis is often decided by reference simply to mathematical convenience. Sometimes the crystals are prominently prismatic only in one direction, as in topaz, and then the axis in this direction is made the vertical. In many cases a cleavage rhombic prism, when there is one, is made the vertical, but exceptions to this are numerous. There is also no general rule for deciding which octahedron should be taken for the unit octahedron. But however decided, the axial relations for the planes will remain essentially the same. In Fig. 10, had the plane lettered $\frac{1}{2}$ been made the plane 1, then the series, instead of being as it is in the figure, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, would have been 2, 1, $\frac{2}{3}$, $\frac{2}{5}$, in which the mutual axial relations are the same.

The relative values of the axes in the orthorhombic system may be calculated in the same way as that of the vertical axis in the tetragonal system, explained on page 35. The law of the tangents, as stated on page 36, holds for this system.

3. Hemihedral Forms.—Hemihedral forms are not common in this system. Some of those so considered have been proved to owe the apparent hemihedrism to their being of the monoclinic system, as in the case of datolite and two species of the chondrodite group. In a few kinds, as, for example, calamine, one extremity of a crystal differs

in its planes from the other. Such forms are termed *hemimorphic*, from the Greek for *half* and *form*. They become polar electric when heated, that is, are pyroelectric, showing that this hemimorphism is connected with polarity in the crystal.

4. **Cleavage.**—Cleavage may take place in the direction of either of the diametral planes (that is, either face of the rectangular prism); but it will be different in facility and in the surface afforded for each. In anhydrite, however, the difference is very small. Cleavage may also occur in the direction of the planes of a rhombic prism, either alone or in connection with cleavage in other directions. It also sometimes occurs, as in sulphur, parallel to the faces of a rhombic octahedron.

5. **Irregularities in Crystals.**—The crystals almost never correspond in their diametral dimensions with the calculated axial dimensions. They are always lengthened, widened, shortened, or narrowed abnormally, but without affecting the angles. Examples of diversity in this kind of distortion are given in Figs. 1 to 7, of barite.

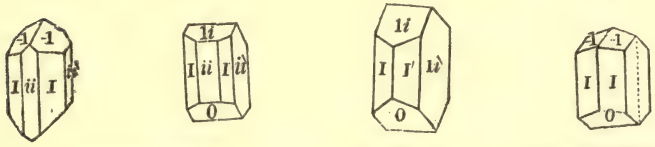
6. **Distinctions.**—In the orthorhombic system the angle 135° does not occur, because the three axes are unequal. There are pyramids of four similar planes in the system, but never of eight; and the angles over the terminal edges of the pyramids are never equal as they are in the tetragonal system. The rectangular octahedron of the orthorhombic system is made up of two horizontal prisms, as shown in Fig. 6, and is therefore not a simple form; and it differs from the octahedron of the tetragonal system corresponding to it (Fig. 16, p. 33) in having the angles over the basal edges of two values.

IV. MONOCLINIC SYSTEM.

1. **Descriptions of Forms.**—In this system the three axes are unequal, as in the orthorhombic system; but one of the axial intersections is oblique, that between the axis a and the vertical axis c. The following examples of its crystalline forms, Figs. 1 to 6, show the effect of this obliquity. On account of it the front or back planes above and below the middle in these figures differ, and the ante-

rior and posterior prismatic planes are unequally inclined to a basal plane.

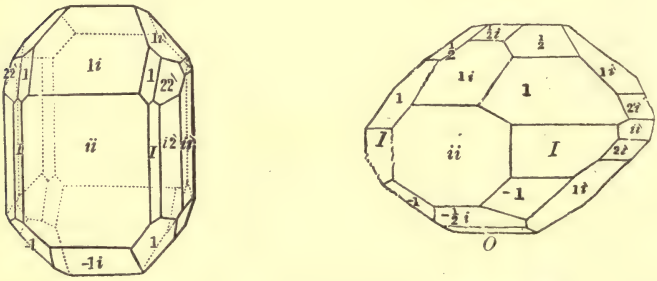
1. 2. 3 4.



PYROXENE. FELDSPAR. HORNBLENDE.

The axes and their relations are illustrated in Figs. 7 and 8. Fig. 7 represents an oblique rectangular prism, and Fig. 8 an oblique rhombic. The former is the diametral prism, like the rectangular of the orthorhombic system. The axes connect the centres of the opposite faces, and the planes are of three distinct kinds, being parallel to unlike axes and diametral sections. In the latter, as in the rhombic prism of the orthorhombic system, the lateral axes connect the centres of the opposite sides. Moreover, this rhombic prism may be reduced to the rectangular by the removal of its edges by planes parallel to the lateral axes.

5. 6.

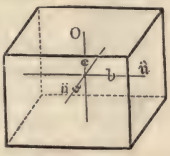


MONAZITE. MIRABILITE.

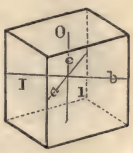
The axis a, or the inclined lateral axis (inclined at an oblique angle to the vertical axis c), is called the *clinodiago-*

nal; and the axis *b*, which is not inclined, the *orthodiagonal* (from the Greek for *right*, or rectangular). The vertical section through the former is called the *clinodiagonal section;* it is parallel to the plane *i-ī* (Figs. 1–6). The vertical section through the latter is the *orthodiagonal section;* it is parallel to planes *i-i*. Owing to the oblique angle between *a* and *c*, the planes above *a* differ in their relations to the axes from those below, and hence comes the difference in the angle they make with the basal plane.

7.



8.



The halves of a crystal either side of the clinodiagonal section—the vertical section through *a* and *c*—*are alike in all planes and angles.* Another important fact is this: that the plane *i-ī*, or that parallel to the clinodiagonal section, is at *right angles* not only to *O* and *i-i*, but to all planes in the zone of *O* and *i-i*; that is, in the clinodiagonal zone; and this is a consequence of the right angle which axis *b* makes with both axis *c* and axis *a*. The plane *i-i* is called the *orthopinacoid*, it being parallel to the orthodiagonal; and the plane *i-ī*, the *clinopinacoid*, it being parallel to the clinodiagonal.

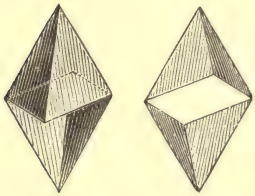
Vertical rhombic prisms have the same relations to the lateral axes as in the orthorhombic system. Domes, or horizontal rhombic prisms, occur in the orthodiagonal zone, because the vertical axis *c* and the orthodiagonal *b* make right angles with one another. In Fig. 6 the planes 1-*ī*, 2-*ī*, belong to two such domes. They are called *clinodomes*, because parallel to the clinodiagonal.

In the clinodiagonal zone, on the contrary, the planes above and below the basal plane differ, as already stated, and hence there can be no orthodomes; they are *hemiorthodomes*. Thus, in Fig. 6, $\frac{1}{2}$-*i*, 1-*i* are planes of hemiorthodomes above *i-i*, and $-\frac{1}{2}$-*i* is a plane of another of different angle below *i-i*. The plane, *and its diagonally opposite*, make the hemiorthodome.

The octahedral planes above the plane of the lateral axes also differ from those below. Thus, in Figs. 5 and 6, the planes 1, 1 are, in their inclinations, different planes from

the planes $-1, -1$; so in all cases. Thus there can be no monoclinic octahedrons—only *hemi-octahedrons*. An oblique octahedron is made up of two sets of planes; that is, planes of two hemi-octahedrons. Such an octahedron may be modelled and figured, but it will consist of two sets of planes: one set including the two above the basal section in front and their diagonally opposites behind (Fig. 9), and the other set including the two below the basal section and their diagonally opposites (Fig. 10).

9. 10.



A hemioctahedron, since it consists of only four planes, is really an obliquely placed rhombic prism, and very frequently they are so lengthened as to be actual prisms.

2. Positions of Planes. Lettering of Crystals.—On account of the obliquity of the crystals, the planes above and below the basal section require a distinguishing mark in their lettering, as well as in the mathematical expressions for them. One set is made *minus* and the other *plus*. The plus sign is omitted in the lettering. In Fig. 7 there are above the basal section (or above $\dot{i}$-$\dot{i}$) the planes 1-$\dot{i}$, $\frac{1}{2}$-$\dot{i}$, 1, $\frac{1}{2}$, but below it, $-\frac{1}{2}$-$\dot{i}$, -1. The *plus* planes are those opposite the acute intersection of the basal and orthodiagonal sections, and the *minus* those opposite the obtuse. No signs are needed for planes of the clinodiagonal section, since they are alike both above and below the basal section.

The distinction of longer and shorter lateral axis is not available in this system, since either may be the clinodiagonal. The distinction of clinodiagonal and orthodiagonal planes is indicated by a grave accent over the number or letters referring to the clinodiagonal. The lettering for the clinodomes on Fig. 6 is 1-$\grave{\imath}$, 2-$\grave{\imath}$—the $\grave{\imath}$ (initial of infinite, with the accent) signifying parallelism to the *clino*diagonal. The hemioctahedrons, 1, 2, etc., need no such mark, as the expression for them is $1c : 1b : 1\grave{a}$, $2c : 1b : 1\grave{a}$, the planes having a unit ratio for $\grave{a}$ and b. But the plane 2-$\grave{2}$, in Fig. 5, requires it, its expression being $2c : 1b : 2\grave{a}$; the fact that the last 2 refers to the clinodiagonal is indicated by the accent. If it referred to the orthodiagonal, that is, if the expression for the plane were $2c : 2b : 1\grave{a}$, it would be written 2-2 without the accent.

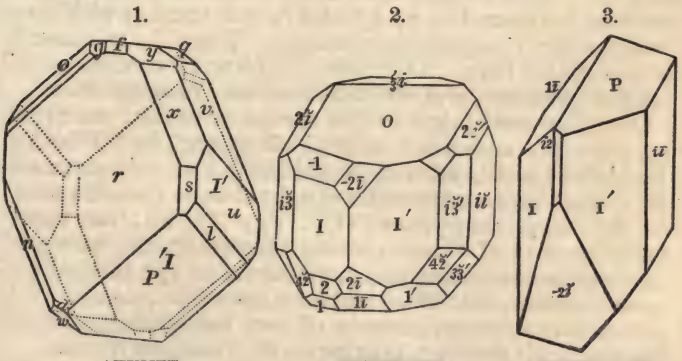
3. Cleavage.—Cleavage may be basal, or parallel to either of the other diametral sections, or parallel to a vertical rhombic prism, or to the planes of a hemioctahedron; or to the planes of a clinodome, or to that of a hemiorthodome. If occurring in two or more directions in any

species it is always different in degree in each different direction, as in all the other systems.

4. **Irregularities.**—Crystals of this system may be elongated abnormally in the direction of either axis, and any diagonal. The hemiorthodomes may be in aspect the bases of prisms, and the hemioctahedrons the sides of prisms. Which plane in the zone of hemiorthodomes should be made the base, and which in the series of hemioctahedrons should be assumed as the fundamental prism determining the direction of the vertical axis, is often decided differently by different crystallographers. Convenience of mathematical calculation is often the principal point referred to in order to reach a conclusion.

V. TRICLINIC SYSTEM.

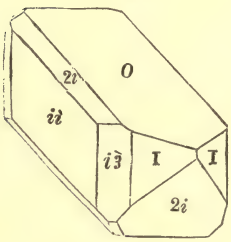
1. **Descriptions of Forms.**—In the triclinic system the three axes are unequal and their three intersections are oblique, and consequently there are never more than two planes of a kind; that is, planes having the same inclinations to either diametral section. The following are examples:



The difference in angle from monoclinic forms is often very small. This is true in the Feldspar family. Fig. 2, of the feldspar called anorthite, is very similar in general form to Fig. 4, of orthoclase, which is monoclinic. This

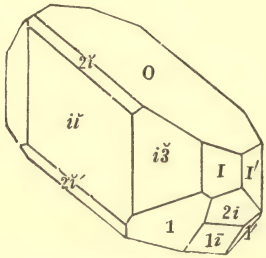
is still more strikingly seen on comparing Fig. 4 with Fig. 5 representing a crystal of oligoclase, another one of the triclinic feldspars. The planes on the two are the same

4.



ORTHOCLASE.

5.



OLIGOCLASE.

with one exception; but there is this difference, that in orthoclase, as in all monoclinic crystals, the angle between the planes *O* and *i*-*i* (the two directions of cleavage) is 90°; and in oligoclase and other triclinic feldspars it is 3° to 6° from 90°, being in oligoclase 93° 50′, and in anorthite 94° 10′. This difference in angle involves oblique intersections between the axes *b* and *c*, and *c* and *a*, which are rectangular in monoclinic forms. There is a similarly close relation between the triclinic form of rhodonite and that of pyroxene, and a resemblance also in composition.

The diametral prism in this system is similar to Fig. 7 on page 43, under the monoclinic system, but differs in having the planes all rhomboidal instead of part rectangular. The form corresponding to the oblique rhombic prism of the monoclinic system (Fig. 8, p. 43) also has rhomboidal instead of rhombic planes; moreover, the two prismatic planes have unequal inclinations to the vertical diametral section, and are therefore dissimilar planes. The prism, consequently, is made of two hemiprisms, and the basal plane is another, making in all three hemiprisms.

2. Cleavage.—Cleavage takes place independently in different diametral or diagonal directions. In the triclinic feldspars it conforms to the directions in orthoclase, with only the exception arising from the obliquity above explained.

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VI. HEXAGONAL SYSTEM.

This system is distinguished from the others by the character of its symmetry—the number of planes of a kind around the vertical axis being a multiple of 3. The number of *lateral* axes is hence 3. It is related to the tetragonal system in having the lateral axes at right angles to the vertical and equal, and is hence like it also in the optical characters of its crystals. Its hexagonal prismatic form approaches orthorhombic crystals in the obtuse angle (120°) of the prism, some orthorhombic crystals having an angle of nearly 120°.

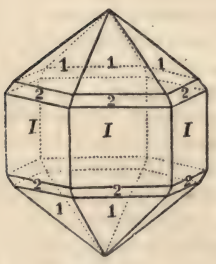
Under this system there are two sections:

1. The HEXAGONAL SECTION, in which the number of planes of a kind around each vertical axis above or below the basal section is 6 or 12.

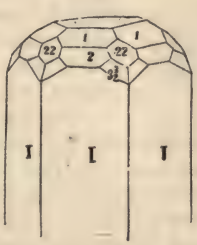
2. The RHOMBOHEDRAL SECTION, in which the number of planes of a kind around each half of the vertical axis, above or below the basal section, is 3 or 6; and, in addition, the planes above alternate in position with those below. The forms are *mathematically* hemihedral to the hexagonal, but not so in their real nature.

I. HEXAGONAL SECTION.

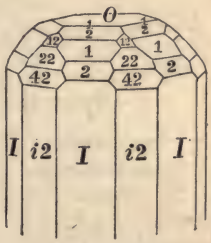
1. Description of Forms.—Figs. 1 to 3 represent some of



MIMETITE.



BERYL.

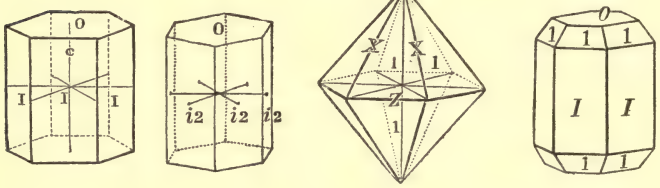


APATITE.

the forms under this section. Figs. 2 and 3 show only one extremity; and such crystals are seldom perfect at both.

All exhibit well the symmetry *by sixes* which characterizes this section of the hexagonal system.

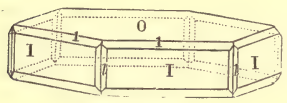
4. 5. 6. 7.



Prisms. Under this system there are two hexagonal prisms and a number of occurring twelve-sided prisms. Fig. 4 represents one of the hexagonal prisms, with its axes—the three lateral connecting the centres of the opposite edges. The lateral angles of the prism are 120°. If the lateral edges of this prism are truncated, as in the figure of apatite (Fig. 3), the truncating planes, *i*-2, are the lateral faces of another similar hexagonal prism, in which, as the relations of the two show, the lateral axes connect the centres of the opposite lateral faces. This prism is represented in Fig. 5.

The lateral edges of the hexagonal prisms occur sometimes with two similar planes on each edge, and these planes, when extended to the obliteration of the hexagonal prism, make a *twelve-sided* prism. These two planes are seen in Fig. 8, along with the planes *I* of the hexagonal prism, and 1 of a double six-sided pyramid, besides the basal plane *O*.

8.



TRIDYMITE.

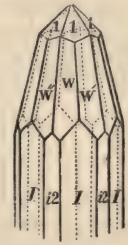
Double pyramids. The double pyramids are of three kinds: (1) A series of six-sided, whose planes belong to the same vertical zone with the planes *I*. The planes of two such pyramids (lettered 1, 2) are shown in Figs. 1 and 2, three of them in Fig. 3 (lettered $\frac{1}{2}$, 1, 2), and one in Fig. 7, and one such double pyramid, without combination with other planes, in Fig. 6. (2) A series of six-sided double pyramids whose planes are in the same vertical zone with *i*-2, examples of which occur on Fig. 2 (plane 2-2) and on Fig. 3 (planes 1-2, 2-2, 4-2). The form of

this double pyramid is like that represented in Fig. 6, but the lateral axes connect the centres of the basal edges. The double six-sided pyramid is sometimes called a *quartzoid*, because it occurs in quartz. (3) Twelve-sided double pyramids. Two planes of such a pyramid are shown on a hexa-

9.

10.

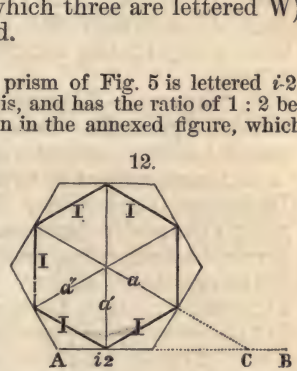
11.



gonal prism in Fig. 9, also in Fig. 2 (the planes 3-$\frac{3}{2}$), and the simple form consisting of such planes in Fig. 10—a form called a *berylloid*, as the planes are common in beryl. In Fig. 11 the planes 1 belong to a double six-sided pyramid; and those next below (of which three are lettered W) to a double twelve-sided pyramid.

2. Lettering of Crystals.—The prism of Fig. 5 is lettered *i*-2, because it is parallel to the vertical axis, and has the ratio of 1 : 2 between two lateral axes. This is shown in the annexed figure, which represents the hexagonal outline of the prism *i*-2 circumscribing that of the prism *I*. The plane *i*-2 is produced to meet axis *a*, which it does when *a* is extended to *twice its length;* whence the ratio for the axes *a*, *a'*, is 1 : 2.

12.



The numbers 1, 2, on the double hexagonal pyramids in Fig. 1 indicate the relative lengths of the vertical axis of the two pyramids, they having the same 1 : 1 ratio of the lateral axes; and so in Figs. 2, 3, and others.

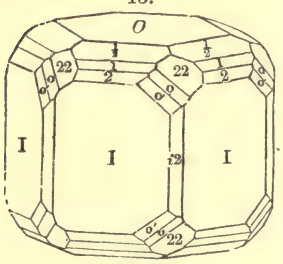
The lettering on the pyramids of the other series in Fig. 3, 1-2, 2-2, 4-2, indicates, by the second figure, that the planes are in the same vertical zone with the prismatic plane *i*-2, and by the first figure the relative lengths of the vertical axes.

In the twelve-sided prisms such ratios as *i*-$\frac{3}{2}$, *i*-$\frac{4}{3}$, *i*-$\frac{5}{4}$ occur. The fraction in any case expresses the ratio of the lateral axes for the particular planes. The double twelve-sided pyramids have the ratios 3-$\frac{3}{2}$

(Fig. 2), 4-$\frac{4}{3}$, and others. Both in these forms and the twelve sided prisms, the second figure in the lettering, expressing the ratio of the lateral axes, has necessarily a value between 1 and 2.

3. Hemihedral Forms.—Fig. 13 represents a crystal of apatite in which there are two sets of planes, *o* (= 3-$\frac{3}{2}$) and *o'* (= 4-$\frac{4}{3}$) which are hemihedral, only half of the full number of each *o* existing, instead of all. This kind of hemihedrism consists in the suppression of an alternate half of the planes in each pyramid of the double twelve-sided pyramid (Fig. 10); and in the suppressed planes of the upper pyramid being here directly over those suppressed in the lower pyramid. If the student will shade over half the planes alternately of the two pyramids in Fig. 10, putting the shaded planes above directly over those below, he will understand the nature of the hemihedrism. In some hemihedral forms the suppressed planes of the upper pyramid alternate with those of the lower; but this kind occurs only in the rhombohedral section of the hexagonal system.

13.

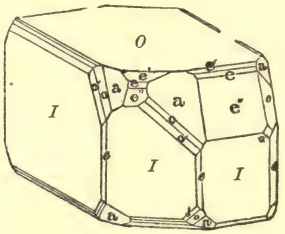


APATITE.

4. Cleavage.—Cleavage is usually basal, or parallel to a six-sided pyramid. Sometimes there are traces of cleavage parallel to the faces of a six-sided pyramid.

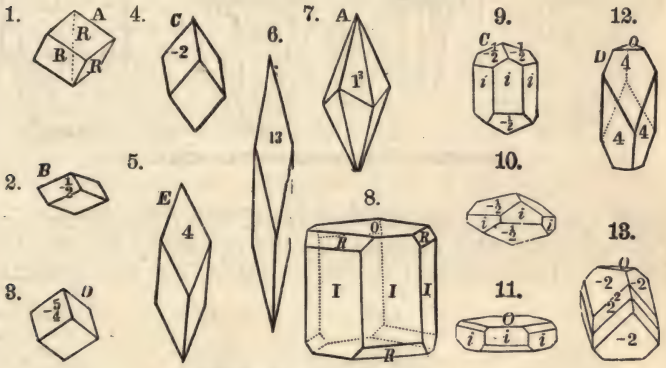
5. Irregularities of Crystals.—Distortions sometimes disguise greatly the real forms of hexagonal crystals by enlarging some planes at the expense of others. This is illustrated in Fig. 14, representing the actual form presented by a crystal having the planes shown in Fig. 13. Whenever in a prism the prismatic angle is exactly 120° or 150°, the form is almost always of the hexagonal system.

14.



2. RHOMBOHEDRAL SECTION.

1. Descriptions of Forms.—The following figures, 1 to 17, represent rhombohedral crystals, and all are of one mineral, calcite. They show that the planes of either end of the crystal are in threes, or multiples of threes, and that those above are alternate in position with those below. There is



FIGURES OF CRYSTALS OF CALCITE.

one exception to this remark, that of the horizontal or basal plane *O*, in Figs. 8, 11, 13.

The simple forms include :

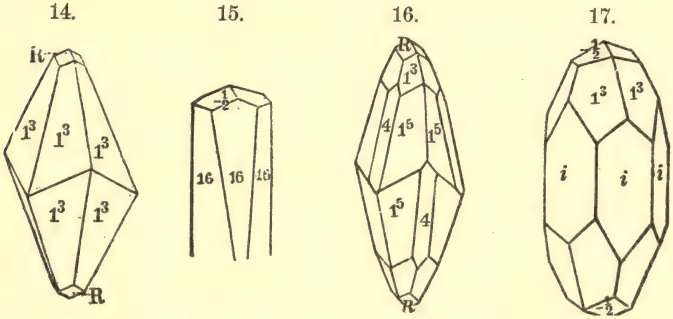
1. *Rhombohedrons,* Figs. 1 to 6. These forms are included under six equal planes, like the cube, but these planes are rhombic ; and instead of having twelve rectangular edges, they have six obtuse edges and six acute.

2. *Scalenohedrons,* Fig. 7. Scalenohedrons are really double six-sided pyramids ; but the six equal faces of each extremity of the crystals are *scalene* triangles, and are arranged in three pairs ; moreover, the pairs above alternate with the pairs below ; the edges in which the pairs above and below meet—that is, the basal edges—make a zigzag around the crystal.

3. *Hexagonal prisms, I,* Fig. 8. Regular hexagonal prisms, having the angle between adjoining faces 120°.

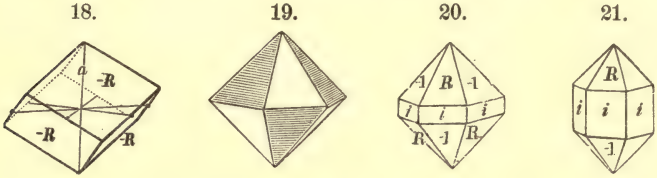
A rhombohedron has two of its solid angles made up of

three equal plane angles. When in position the apex of one of these solid angles is directly over that of the other, as in



FIGURES OF CRYSTALS OF CALCITE.

Figs. 1 to 6, and also in Fig. 18, and the line connecting the apices of these angles (Fig. 18) is called the vertical axis. In this position the rhombohedron has six terminal



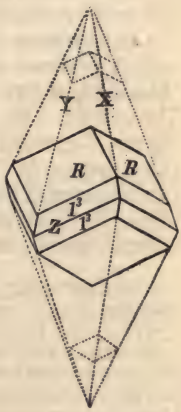
edges, three above and three below, and six lateral edges. As these lateral edges are symmetrically situated around the centre of the crystal, the three lines connecting the centres of opposite basal edges will cross at angles of 60°. These lines are the *lateral axes* of the rhombohedron, and they are at right angles to the vertical axis. It is stated on page 45 that rhombohedral forms are, from a mathematical point of view, *hemihedral* under the hexagonal system. The rhombohedron, which may be considered a double three-sided pyramid, is hemihedral to the double six-sided pyramid. Fig. 19, representing the latter form, has its alternate faces shaded; suppressing the faces shaded, the form would be that of Fig. 18; and suppressing, instead of these, the

faces not shaded, the form would be that of another rhombohedron, differing only in position. The two are distinguished as *plus* and *minus* rhombohedrons. They are combined in Figs. 20, 21, forms of quartz. Rhombohedrons vary greatly in the length of the vertical axis with reference to the lateral. Figs. 1, 2, 3, and 18 represent crystals with the vertical axis short, and Figs. 4, 5, 6 others with a long vertical axis. In the former the angle over a terminal edge is obtuse or over 90°, and that over a lateral, acute; and in the latter the reverse is the case, the angle over the terminal edges being less than 90°; the former are called obtuse rhombohedrons, and the latter acute.

The cube placed on one solid angle, with the diagonal between it and the opposite solid angle vertical, is, in fact, a rhombohedron intermediate between obtuse and acute rhombohedrons, or one of 90°—the edges that are the terminal in this position, and those that are the lateral, being alike rectangular edges. Fig. 3 has nearly the form of a cube in this position.

The relation of one series of scalenohedrons to the rhombohedron is illustrated in Fig. 22. This figure represents a rhombohedron with the lateral edges bevelled. These bevelling planes are those of a scalenohedron, and the outer lines of the same figure show the form of that scalenohedron which is obtained when the bevelment is continued to the obliteration of the rhombohedral planes. Fig. 14 represents this scalenohedron with the rhombohedral planes much reduced in size. Other scalenohedrons result when the terminal edges are bevelled, and still others from pairs of planes on the angles of a rhombohedron.

22.



The scalenohedron is hemihedral to the twelve-sided double pyramid (Fig. 23).

In the hexagonal system the three vertical axial planes divide the space about the vertical axis into six sectors (Fig. 12, p. 50). The twelve-sided double pyramid has in each pyramid a pair of faces for each sector; that is, six pairs for each pyramid. If now the three alternate of these pairs in the lower pyra-

mid, and those in the upper pyramid alternate with these (the shaded in Fig. 23), were enlarged to the obliteration of the rest of the planes, the resulting form would be a scalenohedron—a solid with three pairs of planes to each pyramid instead of six. Such is the mathematical relation of the scalenohedron to the twelve-sided double pyramid. If the faces enlarged were those not shaded in Fig. 23, another scalenohedron would be obtained which would be the *minus* scalenohedron, if the other were designated the *plus*.

23.

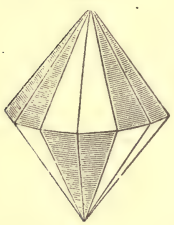


Fig. 8 shows the relations of a rhombohedron to a hexagonal prism. The planes R replace three of the terminal edges at each base of the prism, and those above alternate with those below. The extension of the planes R to the obliteration of those of the prismatic planes, I, and that of the basal plane O, would produce the rhombohedron of Fig. 1. Figs. 9 and 10 represent the same prism, but with terminations made by the rhombohedron of Fig. 2.

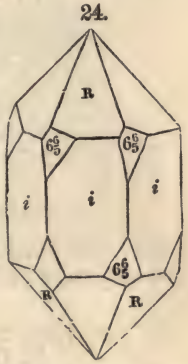
By comparing the above figures, and noting that the planes of similar forms are lettered alike, the combinations in the figures will be understood. Fig. 16 is a combination of the planes of the fundamental rhombohedron R, with those of another rhombohedron 4, and of two scalenohedrons 1^3 and 1^5. Fig. 17 contains the planes of the rhombohedron $-\frac{1}{2}$, with those of the scalenohedron 1^3, and those of the prism i. These figures, and Figs. 14, 22, have the fundamental rhombohedron revolved 60° from the position in Fig. 1, so that two planes R are in view above instead of the one in that figure.

2. Lettering of Figures.—Figs. 1 to 6, representing rhombohedrons of the species calcite, are lettered with numerals, excepting Fig 1. In Fig. 1 the letter R stands for the numeral 1, and the numerals on the others represent the relative lengths of their vertical axes, the lateral being equal. In Fig. 4 the vertical axis is twice that in Fig. 1; in Fig. 6 thirteen times; and in Fig. 15 the planes lettered 16 are those of a rhombohedron whose vertical axis is sixteen times that of Fig. 1. The rhombohedrons of Figs. 1, 5, 6, and 15 are *plus* rhombohedrons; that is, they are in the same vertical series; while 2 and 3 are *minus* rhombohedrons, as explained above. The rhombohedron, when its vertical axis is reduced in length to zero, becomes the single basal plane lettered O in the series. If, on the contrary, the vertical axis of the rhombohedron is lengthened to infinity, the

faces of the rhombohedron become those of a six-sided prism. This last will be seen from the relations of the planes *R* to *I* on Fig. 8, and from the approximation to a prismatic form in the planes 16 of Fig. 15. For an explanation of the lettering of other planes on rhombohedral crystals, reference must be made to the "Text-Book of Mineralogy."

3. Hemihedrism. Tetartohedrism.—Hemihedrism occurs among rhombohedral forms, similar to that in Fig. 13, page 50, except that the suppressed planes of one pyramid are *alternate* with those of the other. One of these is represented in Fig. 24. The planes 6-$\frac{6}{5}$ are six in number at each extremity, and are so situated that they give a spiral aspect to the crystal. If these planes were only three in number at each extremity, the alternate three of the six, the form would be tetartohedral to the double six-sided pyramid; that is, there would be one fourth the number of planes that exist in the double twelve-sided pyramid, or 6 planes instead of 24. Such cases of hemihedrism and tetartohedrism are common in crystals of quartz, and when existing, the crystals are said to be *plagihedral*, from the Greek for *oblique* and *face*. In some crystals the spiral turns *to the right* and in others *to the left*, and the two kinds are distinguished as *right-handed* and *left-handed*. There are also tetartohedral forms in which one whole pyramid of a scalenohedron, or of a rhombohedron, is wanting. For example, in crystals of tourmaline rhombohedral planes, and sometimes scalenohedral, may occur at one extremity of the prism and be absent from the other. This dissimilarity in the two extremities of a crystal of tourmaline is connected with pyro-electric polarity in the mineral. Three-sided prisms, hemihedral to the hexagonal prism, are common in some rhombohedral species, as tourmaline.

24.



4. Cleavage.—Cleavage usually takes place parallel to the faces of a rhombohedron, as in calcite, corundum. Not unfrequently the rhombohedral cleavage is wanting, and there is highly perfect cleavage parallel to the basal plane, as in graphite, brucite.

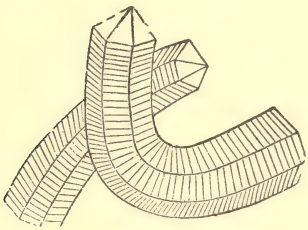
25.

5. Irregularities of Crystals.—Distortions occur of the same nature with those under the other

systems. Some examples are given under quartz. Some rhombohedral species, as dolomite, have the opposite faces convex or concave, as in Fig. 25.

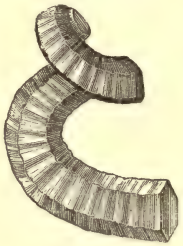
Occasional curved crystals occur, as in Fig. 26, representing crystals of quartz, and Fig. 27 of a crystal of chlo-

26.



QUARTZ.

27.



CHLORITE.

rite. The feathery crystallizations on windows, called frost, are examples of curved forms under this system.

VII. DISTINGUISHING CHARACTERS OF THE SEVERAL SYSTEMS OF CRYSTALLIZATION.

1. Isometric System.—(1) There may be symmetrical groups of 4 and 8 similar planes about the extremities of each cubic axis; and of 3 or 6 similar planes about the extremities of each octahedral axis. (2) Simple holohedral forms may consist of 6 (cube), 8 (octahedron), 12 (dodecahedron), 24 (trapezohedron, trigonal trisoctahedron, and tetrahexahedron), and 48 (hexoctahedron) planes.

2. Tetragonal System.—(1) Symmetrical groups of 4 and 8 similar planes occur about the extremities of the vertical axis only. (2) Prisms occur parallel only to the vertical axis; and these prisms are either square or eight-sided. (3) The simple holohedral forms may consist of 2 planes (the bases), of 4 planes (square prisms), of 8 planes (eight-sided prisms and square octahedrons), of 16 planes (double eight-sided pyramids).

3. Orthorhombic System.—(1) Symmetrical groups of 4 similar planes may occur about the extremities of either axis, but those of one axis may be referred equally to the others. (2) The prisms are rhombic prisms only, and these may occur parallel to either of the axes, the horizon-

tal as well as the vertical. (3) Simple holohedral forms may consist of 2 planes (the bases, and each pair of diametral planes), of 4 planes (rhombic prisms in the three axial directions), and of 8 planes (the rhombic octahedrons). (4) The forms may be divided into equal halves, symmetrical in planes, along each of the diametral sections.

4. MONOCLINIC SYSTEM.—(1) No symmetrical groups of similar planes ever occur around the extremities of either axis. (2) The prisms are rhombic prisms, and these can occur parallel only to the vertical axis and the clinodiagonal. (3) The planes occurring in vertical sections above and below the basal section, either in front or behind, are all unlike in inclination to that section, excepting the prismatic planes in the orthodiagonal zone. (4) Simple forms consist of 2 planes (the bases, the diametral planes, and hemiorthodomes), of 4 planes (rhombic prisms in two directions and hemioctahedrons). (4) The forms may be divided into equal and similar halves only along the clinodiagonal section. No interfacial angle of 90° occurs except between the planes of the clinodiagonal zone and the clinopinacoid.

5. TRICLINIC SYSTEM.—In triclinic crystals there are no groups of similar planes which include more than 2 planes, and hence the simple forms consist of 2 planes only. The forms are not divisible into halves having symmetrical planes. There are no interfacial angles of 90°.

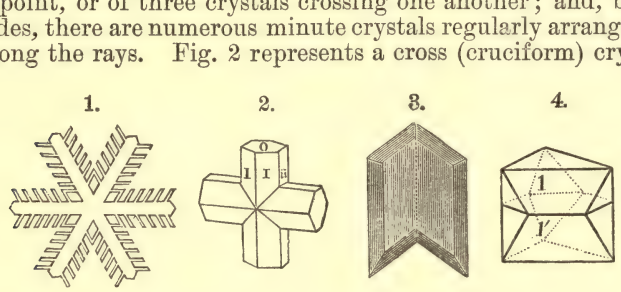
6. HEXAGONAL SYSTEM.—Symmetrical groups of 3, 6, and 12 similar planes may occur about the extremities of the vertical axis. (2) Prisms occur parallel to the vertical axis, and are either six- or twelve-sided (3 in a hemihedral form) and equilateral. (3) Simple holohedral forms may consist of 2 planes (the basal), of 6 planes (hexagonal prism), of 12 planes (twelve-sided prisms and double six-sided pyramids), of 24 planes (double twelve-sided pyramids). Simple rhombohedral forms may consist of 2 planes (the basal), of 6 planes (rhombohedrons), and of 12 planes (scalenohedrons).

The distinguishing optical characters are mentioned beyond.

2. TWIN, OR COMPOUND, CRYSTALS.

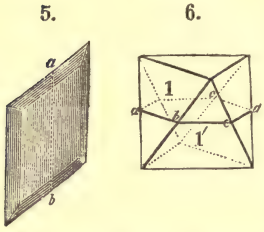
Compound crystals consist of two or more single crystals, united usually parallel to an axial or diagonal section. A few

are represented in the following figures. Fig. 1 represents a crystal of snow of not unfrequent occurrence. As is evident to the eye, it consists either of six crystals meeting in a point, or of three crystals crossing one another; and, besides, there are numerous minute crystals regularly arranged along the rays. Fig. 2 represents a cross (cruciform) crys-



tal of staurolite, which is similarly compound, but made up of two intersecting crystals. Fig. 3 is a compound crystal of gypsum, and Fig. 4 one of spinel. These will be understood from the following figures.

Fig. 5 is a *simple* crystal of gypsum; if it be bisected along *ab*, and the right half be inverted and applied to the other, it will form Fig. 3, which is therefore a twin crystal in which one half has a reverse position from the other. Fig. 6 is a simple octahedron; if it be bisected along the plane *abcde*, and the upper half, after being revolved half way round, be then united to the lower, it will have the form of Fig. 4. Both of these, therefore, are similar twins, in which one of the two component parts is reversed in position.



Crystals like Figs. 3 and 4 have proceeded from a compound nucleus in which one of the two molecules was reversed; and those like Fig. 1, from a nucleus of three (or six) molecules. Compound crystals of the kinds above described thus differ from simple crystals in having been formed from a nucleus of two or more united molecules, instead of from a simple nucleus.

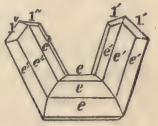
Compound crystals are generally distinguished by their re-entering angles, and often also by the meeting of striæ

at an angle along a line on a surface of a crystal, the line indicating the plane of junction of the two crystals.

Compound crystals are called *twolings, trillings, fourlings,* according as they consist of two, three, or four united crystals. Fig. 1 represents a trilling, and 2, 3, and 4, twolings. In 3 and 4 the combined crystals are simply in contact along the plane of junction; in 2 they cross one another; the former are called *contact-twins* and the latter *penetration-twins.*

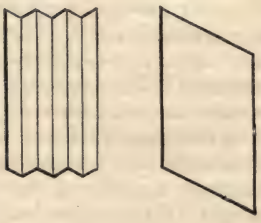
Besides the above, there are also geniculated crystals, as in the annexed figure of a crystal of rutile. The bending has here taken place at equal distances from the centre of the crystal, and it must therefore have been subsequent in time to the commencement of the crystal. The prism began from a simple molecule; but after attaining a certain length an abrupt change of direction took place. The angle of geniculation is constant in the same mineral species, for the same reason that the interfacial angles of planes are fixed; and it is such that a cross-section directly through the geniculation is parallel to the position of a common secondary plane. In the figure given, the plane of geniculation is parallel to one of the terminal edges. In rutile the geniculated crystals sometimes repeat the bendings at each end until the extremities meet to form a wheel-like twin.

7.



In some species, as albite, the reversion of position on which this kind of twin depends, takes place at so short intervals that the crystal consists of parallel plates, each plate often less than a twentieth of an inch in thickness. A section of such a crystal, made transverse to the plate, is given in Fig. 8; without the twinning the section would have been as in Fig. 9. The plates, as the figure shows, make with one another at their edges a re-entering angle (in albite an angle of 172° 48′), and hence a plane of the albite crystal at right angles to the twinning direction, is covered with a series of ridges and depressions

8.

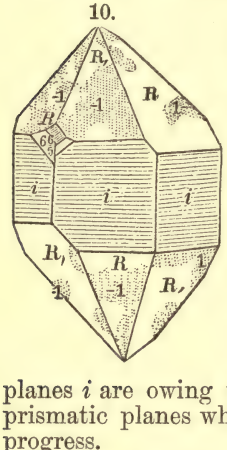


which are so minute as to be only fine striations, sometimes requiring a magnifying power to distinguish. Such striations in albite are therefore an indication of the compound structure.

This kind of twinning is sometimes called *polysynthetic* twinning. It occurs in all the triclinic feldspars, and is a means of distinguishing them from orthoclase. Similar twinning occurs also in calcite, and some other species.

In some twin crystals the two component parts of the crystal are not united by an even plane, but run into one another with great irregularity. Cases of this kind occur in the species quartz in twins made up of the forms R and $-R$ (or -1). In Fig. 10 the shaded parts of the pyramidal planes are of the form -1, and the non-shaded parts of R. Each of the faces is made up partly of R and partly of -1. The limits of the two are easily seen on holding the crystal up to the light, since the -1 portion is less well polished than the other. In this crystal, as in other crystals of quartz, the striations of planes i are owing to oscillations between pyramidal and prismatic planes while the formation of the latter was in progress.

10.



The compound or twinned condition, while often originating in a compound nucleus, and in external molecular influences, may also be produced in many species by pressure or a blow.

In this way a simple rhombohedron of calcite may be made a true twin crystal, or a polysynthetic twin. The grains in a white crystalline limestone or marble—the species calcite or dolomite—are rhombohedral in cleavage, like the ordinary crystals of these minerals; but the cleavage surfaces are usually striated parallel to the longer diameter of the rhombohedral faces, and this striation is due to polysynthetic twinning. It may be always a result of pressure at the time of the crystallization of the limestone. The striations common in the triclinic feldspars have been attributed to the same cause.

3. PARAMORPHS. PARAMORPHISM.

Many examples exist in which elements, and compounds that have the same composition essentially, differ in crystalline form as well as other physical qualities. These are examples of *paramorphism*. Among the elements, one marked example is *carbon*, which is isometric in the diamond, but hexagonal in graphite: of extreme hardness, adamantine lustre, and a specific gravity of 3·53 in the former; of extreme softness, a metallic lustre, and a specific gravity of 2·1 in the latter. Such differences may be conceived of as due to differences in molecular condensation. The following are examples among compounds: *Calcium carbonate* occurs rhombohedral (and G. = 2·72) in calcite, orthorhombic (and G. = 2·93) in aragonite. *Silica* is rhombohedral (the hemihedral section of the hexagonal system) (and G. = 2·65) in quartz; true hexagonal (G. = 2·29) in tridymite; and uncrystallizable in opal (G. = 2·17). *Titanium dioxide* has an orthorhombic form in brookite, one tetragonal form in rutile, and another tetragonal in octahedrite. In the hornblende group, hornblende and pyroxene are alike in composition and in monoclinic crystallization; but the former has a cleavage angle of 124° 30′, and the latter of 87° 5′. In addition, other species of the group having these two cleavage angles, as anthophyllite and enstatite, are orthorhombic in crystallization.

In general one of the forms is less stable under the ordinary temperature or conditions than the other, because it requires for formation a higher temperature or some other unusual condition. Thus pyroxene is less stable than hornblende; aragonite than calcite, brookite than rutile.

4. PSEUDOMORPHS, PSEUDOMORPHISM.

The crystalline forms under which a species occurs are sometimes those of another species. Quartz often has the crystalline form of calcite, owing to a substitution of silica for the calcium carbonate of the calcite crystal. Serpentine has often the form of chrysolite, chondrodite, or some other magnesium mineral, owing to a change in these other magnesium silicates into the hydrous magnesium silicate

called serpentine. Such false forms are called *pseudomorphs*, from the Greek *pseudos*, false, and *morphe*, form. The same process that turned the calcite into quartz has converted wood, shells, and corals into quartz; in other words, made silicified wood, shells, and corals.

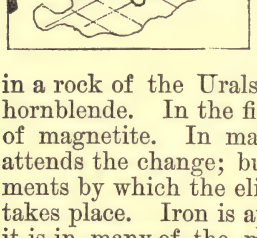
The different kinds of pseudomorphism are the following:

1. By *substitution:* as in the substitution of silica (quartz) for the calcite.

2. By *chemical alteration:* as in the change to serpentine above explained; or the change of iron carbonate (siderite) to the hydrous iron oxide (limonite).

3. By *impression:* as in deposition in a cavity once occupied by a crystal; or against the exterior of a crystal.

4. By *paramorphism:* as when pyroxene becomes changed to hornblende, or aragonite to calcite. In this alteration of pyroxene, as fast as the outer part becomes changed, it has cleavage parallel to the hornblende prism ($I \wedge I = 124° 30''$), instead of that of pyroxene ($87° 5'$), as in the accompanying figure, which in its central part represents a transverse section of a crystal, the centre pyroxene, the outer part hornblende, and in the upper corner a longitudinal section of a similarly altered pyroxene. The cleavage-lines are often an indication of its progress. Such hornblende has been called *uralite*, because first observed (by H. Rose) in a rock of the Urals; but it is essentially like ordinary hornblende. In the figure the black spots represent grains of magnetite. In many cases no change in composition attends the change; but in others there are some replacements by which the elimination of unessential ingredients takes place. Iron is apt to be this removed ingredient, as it is in many of the methods of chemical alteration; and, consequently, while it remains in the crystal it takes an independent form, and usually that of minute grains or crystals of magnetite, or hematite, or menaccanite.



5. CRYSTALLINE AGGREGATES.

The crystalline aggregates here included are the simple, not the mixed; that is, they are those consisting of crystalline individuals of a single species.

The crystalline individuals may be (1) distinct crystals; (2) fibres or columns; (3) scales or lamellæ; or (4) grains, either cleavable or not so.

1. *Consisting of distinct crystals.*—The *distinct crystal* may be either long or short *prismatic,* stout or slender to *acicular* (needle-like), and *capillary* (hair-like); or they may have any other forms of crystals. They may be aggregated (*a*) in lines; (*b*) promiscuously with open spaces; (*c*) over broad surfaces; (*d*) about centres. The various kinds of aggregates thus made are:

a. Filiform.—Thread-like lines of crystals, the crystals often not well defined.

b. Dendritic.—Arborescent slender spreading branches, somewhat plant-like, made up of more or less distinct crystals, as in the frost on windows, and in arborescent forms of native copper, silver, gold, etc.

Fig. 11 represents, much magnified, an arborescent form of magnetite occurring in mica at Pennsbury, in Pennsylvania. Arborescent delineations over surfaces of rock are usually called *dendrites.* They have been formed by crystallization from a solution of mineral matter which has entered by some crack and spread between the layers of the rock. They are often black, and consist of oxide of manganese; others, of a brownish color, are made of limonite; others, of a reddish black or black color, of hematite. Moss-like forms also occur, as in moss agate.

11.

c. Reticulated.—Slender prismatic crystals promiscuously crossing, with open spacings.

d. Divergent.—Free crystals radiating from a central point.

e. Drusy.—A surface is *drusy* when covered with implanted crystals of small size.

2. Consisting of *columnar individuals.*

a. Columnar, when the columnar individuals are stout.

b. Fibrous, when they are slender.

c. Parallel fibres, when the fibres are parallel.

d. Radiated, when the columns or fibres radiate from centres.

e. Stellated, when the radiations from a centre are equal around, so as to make star-like or circularly-radiated groups.

f. Globular, when the radiated individuals make globular or hemispherical forms, as in wavellite.

g. Botryoidal, when the globular forms are in groups, a little like a bunch of grapes. The word is from the Greek for a bunch of grapes.

h. Mammillary, having a surface made up of low and broad prominences. The term is from the Latin *mammilla,* a *little teat.*

i. Coralloidal, when in open-spaced groupings of slender stems, looking like a delicate coral. A result of successive additions at the extremity of a prominence, lengthening it into cylinders, the stems generally having a faintly radiated structure.

Specimens of all these varieties of columnar structure, excepting the last, often have a *drusy* surface, the fibres or columns ending in projecting crystals.

3. *Consisting of scales or lamellæ.*

a. Plumose, having a divergent arrangement of scales, as seen on a surface of fracture; *e.g.,* plumose mica.

b. Lamellar, tabular, consisting of flat lamellar crystalline individuals, superimposed and adhering.

c. Micaceous, having a thin fissile character, due to the aggregation of scales of a mineral which, like mica, has eminent cleavage.

d. Septate, consisting of openly-spaced intersecting tabular individuals; also divided into polygonal portions by reticulating veins or plates. A *septarium* is a concretion, usually flattened spheroidal in shape, the solid interior of which is intersected by partitions; these partitions are the fillings of cracks in the interior that were due to contraction on drying. Such septate concretions, especially when worn off at surface, often have the appearance of a turtle's back, and are sometimes taken for petrified turtles.

4. *Consisting of grains. Granular structure.*—A massive mineral may be *coarsely granular* or *finely granular*, as in varieties of marble, granular quartz, etc. It is termed *saccharoidal* when evenly granular, like loaf-sugar. It may also be *cryptocrystalline*, that is, having no distinct grains that can be detected by the unaided eye, as in flint. The term cryptocrystalline is from the Greek for *concealed crystalline*. *Aphanitic*, from the Greek for *invisible*, has the same signification. The term *ceroid* is applied when this texture is connected with a waxy lustre, as in some common opal.

Under this section occur also *globular*, *botryoidal*, and *mammillary* forms, as a result of concretionary action in which no distinct columnar interior structure is produced. They are called *pisolitic* when in masses consisting of grains as large as peas (from the Latin *pisum*, *a pea*), and *oölitic* when the grains are not larger than the roe of a fish, from the Greek for *egg*.

5. *Forms depending on mode of deposition.*—Besides the above, there are the following varieties which have come from mode of deposition:

a. Stalactitic, having the form of a cylinder, or cone, hanging from the roofs of cavities or caves. The term stalactite is usually restricted to the cylinders of calcium carbonate hanging from the roofs of caverns; but other minerals are said to have a stalactitic form when resembling these in their general shape and origin. Chalcedony and limonite are often stalactitic. Interiorly the structure may be either granular, radiately fibrous, or concentric.

The waters percolating through the roofs of limestone caverns hold some limestone in solution; and the deposit which each successive drop of water makes, lengthens out the cylinder; and not unfrequently they become yards in length, or reach from roof to floor. The stalactites are sometimes hollow cylinders when small, because the drops, which follow one another very slowly, evaporate chiefly at the outer margin of each, the first one thus making a ring, and the following lengthening the ring into the cylinder. The solution is strictly a solution of calcium *bicarbonate;* as evaporation takes place the excess of carbonic acid goes off and calcium carbonate is deposited.

b. Concentric.—When consisting of lamellæ, lapping one over another around a centre, a result of successive concretionary aggregations, as in many *concretionary* forms, most *pisolite*, part of *oölite*, some *stalactites*, etc.

c. Stratified, consisting of layers, as a result of deposition: *e.g.*, some travertine, or tufa.

d. Banded, straticulate; color-stratified. Like stratified in origin, but the layers thin and usually indicated only by variations in color or texture; the banding is shown in a transverse section: *e.g.*, agate, much stalagmite, riband jasper, some limestone; it becomes lamellar or slaty when the little layers are separable.

e. Geodes.—When a cavity has been lined by the deposition of mineral matter, but not wholly filled, the enclosing mineral is called a geode. The mineral is often banded, owing to the successive depositions of the material, and frequently has its inner surface set with crystals. Agates are often slices or fragments of geodes.

6. *Fracture.*—Kinds of fracture in these crystalline aggregates depend on the size and form of the particles, their cohesion, and to some extent their having cleavage or not.

Among granular varieties, the influence of cleavage is in all cases very small, and in the finest almost or quite nothing. The term *hackly* is used for the surface of fracture of a metal, when the grains are coarse, hard, and cleavable, so as to be sharp and jagged to the touch; *even*, for any surface of fracture when it is nearly or quite flat, or not at all conchoidal; *conchoidal*, when the mineral, owing to its extremely fine or cryptocrystalline texture, breaks with shallow concavities and convexities over the surface, as in the case of flint. The word conchoidal is from the Latin *concha*, a shell. These kinds of fracture are not of great importance in mineralogy, since they distinguish varieties of minerals only, and not species.

II. PHYSICAL PROPERTIES OF MINERALS.

THE physical properties referred to in the description and determination of minerals are here treated under the following heads: (1) Hardness; (2) Tenacity; (3) Specific Gravity; (4) Refraction, Polarization; (5) Diaphaneity, Color, Lustre; (6) Electricity and Magnetism; (7) Taste and Odor. All excepting the last are more or less dependent on the crystallization, the qualities in each case being alike in crystals in the direction of like or equal axes, and usually unlike in the directions of unlike or unequal axes.

1. HARDNESS.

The comparative hardness of minerals is easily ascertained, and should be the first character attended to by the student in examining a specimen. It is only necessary to draw a file across the specimen, or to make trials of scratching one with another. As standards of comparison the following minerals have been selected, increasing gradually in hardness from *talc*, which is very soft and easily cut with a knife, to the *diamond*. This table, called the *scale of hardness*, is as follows:

1, *talc*, common foliated variety; 2, *rock-salt*; 3, *calcite*, transparent variety; 4, *fluorite*, crystallized variety; 5, *apatite*, transparent crystal; 6, *orthoclase*, cleavable variety; 7, *quartz*, transparent variety; 8, *topaz*, transparent crystal; 9, *sapphire*, cleavable variety; 10, *diamond*.

If, on drawing a file across a mineral, it is impressed as easily as *fluorite*, the hardness is said to be 4; if as easily as *orthoclase*, the hardness is said to be 6; if more easily than orthoclase, but with more difficulty than apatite, its hardness is described as $5\frac{1}{2}$ or 5·5.

The file should be run across the mineral three or four times, and care should be taken to make the trial on angles equally blunt, and on parts of the specimen not altered by exposure. Trials should also be made by scratching the specimen under examination with the minerals in the above scale, since sometimes, owing to a loose aggregation of particles, the file wears down the specimen rapidly, although the particles are very hard.

In crystals the hardness is sometimes appreciably different in degree in the direction of different axes. In crystals of mica the hardness is less on the basal plane of the prism, that is, on the cleavage surface, than it is on the sides of the prism. On the contrary, the termination of a crystal of cyanite is harder than the lateral planes. The degree of hardness in different directions may be obtained with great accuracy by means of an instrument called a *sclerometer*.

2. TENACITY.

The following rather indefinite terms are used with reference to the qualities of tenacity, malleability, and flexibility in minerals:

1. *Brittle.*—When a mineral breaks easily, or when parts of the mineral separate in powder on attempting to cut it.

2. *Malleable.*—When slices may be cut off, and these slices will flatten out under the hammer, as in native gold, silver, copper.

3. *Sectile.*—When thin slices may be cut off with a knife. All malleable minerals are sectile. Argentite and cerargyrite are examples of sectile ores of silver. The former cuts nearly like lead, and the latter nearly like wax, which it resembles. Minerals are *imperfectly sectile* when the pieces cut off pulverize easily under a hammer, or barely hold together, as selenite.

4. *Flexible.*—When the mineral will bend, and remain bent after the bending force is removed. Example, talc.

5. *Elastic.*—When, after being bent, it will spring back to its original position. Example, mica.

A liquid is said to be *viscous* when on pouring it the drops lengthen and appear ropy.

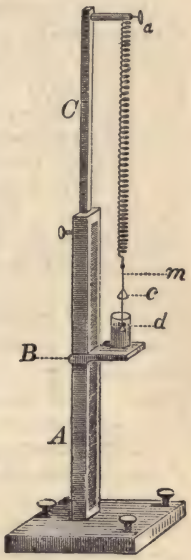
3. SPECIFIC GRAVITY.

The specific gravity of a mineral (called also its density) is its weight compared with that of some substance taken as a standard. For solids and liquids *distilled water*, at 60° F., is the standard ordinarily used; and if a mineral weighs twice as much as water, its specific gravity is 2; if three times it is 3. It is then necessary to compare the weight of the mineral with the weight of an equal bulk of water. The process is as follows:

First weigh a fragment of the mineral in the ordinary way, with a delicate balance; next suspend the mineral by a hair, or fibre of silk, or a fine platinum wire, to one of the scales, immerse it, thus suspended, in a glass of distilled water (keeping the scales clear of the water) and weigh it again; subtract the *second* weight from the *first*, to ascertain the loss by immersion, and divide the *first* by the difference obtained; the result is the specific gravity. The loss by immersion is equal to the weight of an equal volume of water. The trial should be made on a small fragment; two to five grains are best. The specimen should be free from impurities and from pores or air-bubbles. For exact results the temperature of the water should be noted, and an allowance be made for any variation from the height of

thirty inches in the barometer. The observation is usually made with the water at a temperature of 60° F.; 39°·5 F., the temperature of the maximum density of water, is preferable.

The accompanying figure represents the spiral balance of Jolly, by which the density is measured by the torsion of a spiral brass wire. On the side of the upright (*A*) which faces the spiral wire, there is a graduated mirror, and the readings which give the weight of the mineral in and out of water are made by means of an index (at *m*) connected with the spiral wire; and its exact height, with reference to the graduation, is obtained by noting the coincidence between it and its image as reflected by the graduated mirror. *c* and *d* are the pans in which the piece of mineral is placed, first in *c*, the one out of the water, and then in *d*, that in the water.



In using the spiral balance the spiral spring is put at any desired height by means of the sliding-rod *C*. The stand B is raised so that the lower pan, *d*, shall be in the water, while the other, *c*, is above it. The position of the index, or signal, *m*, is then noted, by sighting across it and observing that the index and the image of it in the mirror are in the same horizontal line; let *s* stand for it. Next put the fragment of the mineral in *c*, and drop the stand *B* until the lower pan hangs free in the water, and note the position of *m*, which we may represent by *t*; $t-s$ represents the weight in the air. Now place the fragment in the lower pan, and after adjusting again the stand *B*, the position of *m* is noted as before; call it *u*. Then $t-u=$ loss of weight in water. From these values the specific gravity is at once obtained.

Another process, and one available for *porous* as well as compact minerals, is performed with a light glass bottle, capable of holding exactly a thousand grains (or any known weight) of distilled water. The specimen should be reduced to a coarse powder. Pour out a few drops of water

from the bottle and weigh it; then add the powdered mineral till the water is again to the brim, and reweigh it; the difference in the two weights, divided by the loss of water poured out, is the specific gravity sought. The weight of the glass bottle itself is here supposed to be balanced by an equivalent weight in the other scale.

Another method consists in the use of a solution of a salt of high specific gravity. The *potassium-mercury iodide* is one salt so used, and another is the *cadmium boro-tungstate*. The maximum density of a solution of the former is 3·2; of the latter, 3·6. By carefully adding water, the solution is reduced in density to that of the mineral, or that in which the mineral in coarse grains will just float; and this density is then determined by weighing a given amount of the solution. The process is used also for the separation of mixed minerals of unequal density. Details of the processes will be found in larger works.

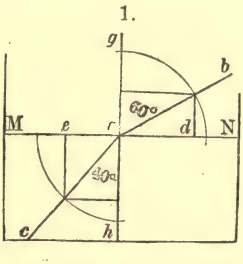
4. REFRACTION AND POLARIZATION.

Light is *refracted* when it passes from a rarer medium through a denser, as from air through water, or the reverse. It is *polarized*, or has its vibrations reduced to *vibrations in a plane*, when it passes through a crystal of unequal crystallographic axes, or a fragment of such a crystal.

Amorphous substances (or those totally devoid of traces of crystallization), like glass and opal, and *crystallized* substances of the *isometric* system, have *single* or *simple* refraction; while substances crystallized under either of the other systems of crystallization have *double* refraction.

Simple Refraction.—The *index* of ordinary refraction is obtained by dividing the sine of the angle of incidence of the ray of light by the sine of its angle of refraction. Thus if a ray of light (*ab*, Fig. 1) strike the surface (*MN*) of the denser material at an angle of 60° from the perpendicular (the angle *bag*), and then passes through it at an angle of 40° from the perpendicular (angle *cad*), the sine of 60° (*ad*), divided by the sine of 40° (*ae*), will be the index of refraction.

1.



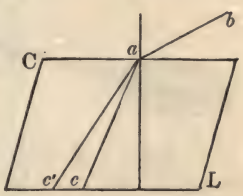
The index of refraction of air being taken as the unit,

that of water, as experiment has ascertained, is 1·335; of fluorite, 1·434; of rock-salt, 1·557; of spinel, 1·764; of garnet, 1·815; of blende, 2·260; of diamond, 2·439.

Isometric and amorphous substances are said to be *isotropic*, because in them the velocity of light and all light-phenomena are alike in all directions.

Double Refraction. Polarization.—Double refraction is illustrated in the annexed figure representing a transparent rhombohedron of calcite, with the ray, *ab*, divided, as it passes through the crystal, into two rays *ac* and *ac'*. When such a crystal is placed over a dot the dot appears double, owing to the double refraction. Each of these rays is a *polarized* ray.

2.



Such crystals are optically either *uniaxial* or *biaxial*.

A. *Uniaxial.*—Uniaxial substances are those of the tetragonal and hexagonal systems; and the *vertical* axis, about which the parts are arranged symmetrically, is the *optic axis*. In the direction of this axis refraction is simple, but in all other directions *double;* and the divergence is greatest in a direction at right angles to the vertical or optic axis.

One of the rays has its vibrations *transverse* to the axis: it is called the *ordinary* ray, because it obeys the laws of ordinary refraction above explained. The other, the *extraordinary* ray, has its vibrations in the direction of the axis, and obeys a different law, because the elasticity of the light-ether in this direction is greater or less than in the transverse. If the index of refraction of the extraordinary ray (ϵ) is greater than that of the ordinary (ω), the crystal is said to be *positive;* if less, it is *negative*. Calcite is an example of a negative crystal, *ac* in Fig. 2 being the extraordinary ray; and quartz is an example of a positive.

Plates of tourmaline made by vertical sections of a transparent crystal transmit the extraordinary ray, while the ordinary ray is absorbed. Hence such plates are convenient for optical investigations. A simple *polariscope* made of two tourmaline plates has the form in Fig. 3. The effects are the same whichever tourmaline plate is brought to the eye. The plate away from the eye, or that receiving the light for transmission, is called the *polarizer*,

and the other the *analyzer*. Light passes freely through the two plates as long as they have the position they had in the crystal, that is, have the vertical axes—the planes of vibration—of the two *parallel*. But if the axes are *crossed*, by revolving one plate 90°, no light passes. In a revolu-

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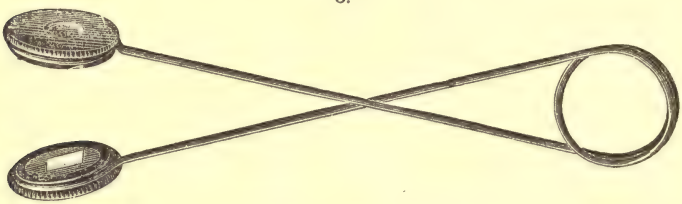


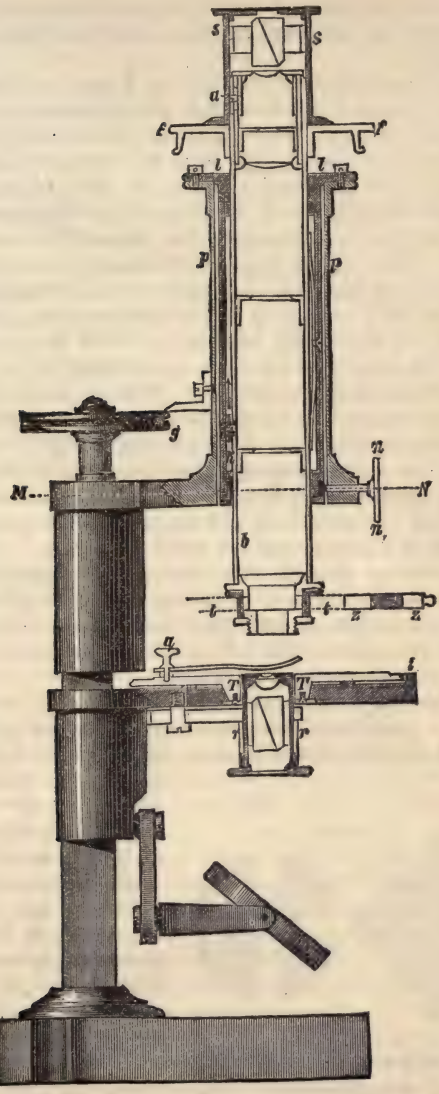
tion, light and dark fields alternate every 90°. Crystalline minerals are examined by placing sections of them between the tourmalines.

Calcite, owing to the wide divergence of its refracted rays, is commonly used for polarizing apparatus. In a "nicol prism" of calcite (Fig. 4) the extraordinary ray (ac') passes through the prism, while the other (ac) is got rid of by reflection from the surface of Canada balsam (mn) along which the two pieces of calcite in the prism are joined.

4.

In a polariscope the two nicols are mounted in tubes, one of which, if the instrument is a vertical one, is placed above, and the other below, a stage arranged for receiving the object for examination. One or both of the nicols, and also the stage, admits of revolution, in order to place the planes of vibration of the nicols in different positions as to one another and as to the specimen centered on the stage; and graduated scales indicate the angle of revolution in nicol and stage. Lenses for magnifying the object are added; and also others, making what is called the *condenser*, which is placed between the polarizer and the stage.

In the ordinary polariscope, only very low magnifying-powers are used without an ocular, and consequently the field is large so as to be convenient for observations on the light-phenomena. By inserting the condenser the trans-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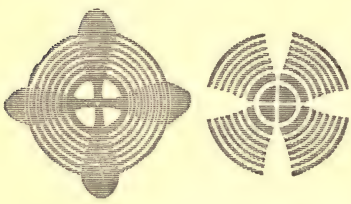
mission of the polarized light in *parallel* rays is changed to transmission in *convergent* rays; and the light-phenomena are changed.

In the polarization-microscope (a figure of which is here introduced) higher powers are used, and also an ocular (eye-piece with lenses). The nicols are at *ss* (analyzer) and *rr* (polarizer); the supporting tube of the analyzer revolves, and rests on a graduated circle *ff*, with a mark on the edge which is to be set at 0° to put the vibration-planes of the two nicols in a *crossed* position, and at 90° to make them *parallel*. The tube of the microscope moves up and down, by the hand, within the outer case *pp*; and a fine adjustment is obtained with the screw *g*, the surface of which is graduated. In the figure the condenser *TT* is in place, as when required for observations with converging rays (which are made with the ocular removed). The stage revolves and has a lateral movement by screws to aid in centering the object; and to give further aid, the tube has a slight movment by the screw *nn*. *tt* is an opening for inserting a plate of quartz (*ZZ*,) for determining the precise position when an axis of elasticity of the object on the stage coincides with a vibration-plane of a nicol, and for other purposes.

On revolving one of the nicols, the change from the transmission of light to its non-transmission by the analyzer, or the "extinction of the ray," takes place with every 90° of revolution, as with the tourmaline polariscope; and alike for *parallel* and *converging* light.

If a plate of a uniaxial crystal *cut at right angles to the vertical or optic axis* is on the stage centered in the field of view, and the nicols are *crossed* and *parallel light* is used, the field remains dark through the complete revolution of the stage, as in the case of isometric and isomorphous substances; but if *converging light* is used in the polariscope, a symmetrical black cross and concentric spectrum-circles are seen when the nicols are *crossed* (Fig. 6), and a light-cross with the colors reversed (Fig. 7) when they are *parallel*. The number of spectrum-rings

6. 7.



within the field under a given convergence and magnifying-power depends on the refraction and the thickness of the plate under examination. The plate may be so thin that it will have but one color, or none. The tourmaline-polariscope affords the same cross and circles or "interference-figures," because the eye is brought so closely to the analyzer in making observations that the light is really converging light.

When the ordinary thin sections mounted on glass are examined in the polarization-microscope, it is commonly the case, owing to the thinness of the sections, that few if any of the colored rings around the centre of the black cross are in sight. If the sections for examination, instead of being cut parallel to the base of the crystal, or at right angles to the optic axis, are cut a little oblique to it but at right angles still to a vertical axial section, the cross will be symmetrical, but its centre out of the centre of the field; and if cut much oblique to it, its centre may be wholly out of the field, and only one straight black band be visible.

Circular polarization characterizes *quartz*. The light-vibrations instead of being in a single plane rotate either to the right or left, according as the crystal is right-handed or left-handed (p. 55). Consequently, a plate cut at right angles to the optic or vertical axis has a colored centre to the series of spectrum-circles in all positions of the analyzer; moreover, on revolving the analyzer the color of the centre changes from blue to yellow and red in *right*-handed crystals if the revolution is to the right, and in *left*-handed when the revolution is in the opposite direction.

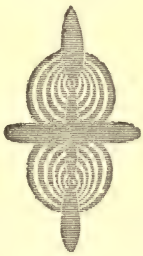
B. *Biaxial.*—1. In *orthorhombic*, *monoclinic*, and *triclinic* crystals the three crystallographic axes are unequal, and there is unequal elasticity optically in three directions *at right angles with one another:* a maximum axis (a), a mean (b), and a minimum (c). The elasticity in these directions is inversely as the refraction-indices for the same directions.

There are *two* directions in which there is no double refraction, and these are the directions of the two *optic axes*. The two are situated in a plane passing through the axes of maximum and minimum elasticity (a and c), and coincide with lines in this plane along which the elasticity equals that of the mean axis. A line bisecting the acute angle of intersection of the two optic axes is called the *acute bisec-*

trix, and that for the obtuse angle of intersection, the *obtuse bisectrix*.

Sections of such crystals cut at right angles to a bisectrix (but best the *acute* bisectrix, for the angle bisected by the obtuse is too divergent for viewing well the phenomena) show in converging polarized light, when the plate under examination has the line joining the axes coincident with the vibration-plane of either nicol-prism, a black band or an *unsymmetrical* black cross, similar to that in Fig. 8; if a revolution of 45° is made, the form changes to that in Fig. 9. But the plates under investigation may be so thin or the axis so divergent that the axial centres are not in the field of view.

8. 9.



2. In the *Orthorhombic system* the three axes of elasticity *coincide in direction with* the crystallographic axes. The plane of the two optic axes coincides with one of the three axial sections: *which* of the three is to be determined by observations on sections cut parallel to each.

In observations made with parallel light on sections cut parallel to the axial planes, extinction of the light takes place whenever the cross-wires in the polarization-microscope are parallel with the axes of elasticity (or the crystallographic axes) in the section. The extinction, under the orthorhombic system, is hence said to be *parallel extinction*.

3. In *monoclinic* crystals (which have but one plane of symmetry—the clinodiagonal, and one axis—the orthodiagonal, at right angles to the plane of the other two) one of the axes of elasticity coincides in direction with the orthodiagonal, and the other two (at right angles with it) lie in the plane of symmetry. Either of the three may be that of maximum (a), mean (b), or minimum (c) elasticity.

The plane of the two optic axes may coincide with either of the three planes passing through the axes of elasticity (one of which planes is that of the clinodiagonal section, and the other two are planes at right angles to the clinodiagonal section passing through the orthodiagonal and one

other of the axes of elasticity in that section); and when situated in the clinodiagonal section they are unsymmetrical in crystallographic relations, but when in either of the other sections they are situated symmetrically either side of the clinodiagonal section.

With reference to observations with parallel light in the polarization-microscope, it is to be noted that—since the plane of the vertical crystallographic axis and axis of elasticity makes a right angle with the orthodiagonal, like the planes of vibration of the crossed nicols, but an oblique angle with the clinodiagonal, any section made in the orthodiagonal zone (or at right angles to the clinodiagonal section) will have extinction *parallel*, as in the orthorhombic system; but in the case of sections cut in other directions, extinction does not take place when either of the planes or cleavage lines in the clinodiagonal section is brought to parallelism with either vibration-plane of the nicols, and a revolution through an angle—different for different species and positions—has to be made: the amount of this angle is called the *extinction-angle* as measured from the edge or cleavage-line selected for the measurement. For hornblende and pyroxene, in which the optic axes lie in the plane of symmetry, the extinction-angle is measured from the cleavage-lines, these being parallel to the vertical axes; it is 15° for hornblende; 39° for pyroxene; while *parallel*, or 0° (expressed by the symbol ||) for enstatite and hypersthene which are orthorhombic.

The following figures represent clinodiagonal sections of hornblende and pyroxene, having *cc* as the vertical axis, and *aa* as the clinodiagonal, with the angle of extinction marked upon them. *AA*, *BB* are the two optic axes, and a, c the two axes of elasticity.

The point of light-extinction is more exactly determinable if a basal section of calcite is placed between the ocular and analyzer, and the precise moment observed when the distortion of the interference-figures of the calcite ceases. But for microscopic investigations a quartz-plate or a Calderon artificial twin of calcite is used. The quartz-plate is inserted above the objective. The nicols being crossed and the analyzer revolved until a particular color, say violet, is obtained, then, on placing the section on the stage, the color will be changed, and will remain different until *one of the axes of elasticity* in the section corresponds with a vibra-

tion-plane in the nicols, when it will be violet again. This is the point desired.

4. In the *triclinic* system, since there is no plane of

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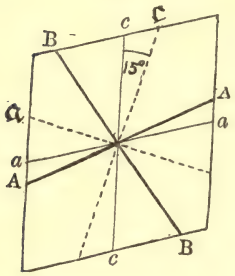
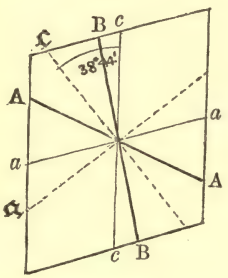


HORNBLENDE.

11.



PYROXENE.

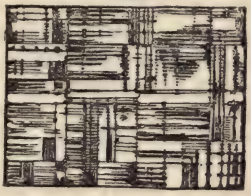
symmetry, and the crystallographic axes have no rectangular intersections, the positions of the axes of elasticity and of the optic axes have to be determined by the optical examination of sections cut in different directions, and by the angles of extinction measured from different faces of the crystal or cleavage-lines. Some hints as to the positions of the axes may often be derived from their positions in related monoclinic forms of similar chemical compounds; as, for the triclinic feldspars from the monoclinic, for rhodonite from pyroxene, etc. In the triclinic feldspars the extinction-angle is usually measured from the edge between the two cleavage-planes, or parallel to the shorter diagonal of *O*. The angle differs for the different kinds, and is the chief means of microscopical determination.

5. *Compound crystals*, the isometric excepted, are compound in their optical characters as well as form. The component parts have their crystallographic axes in different positions, and hence also their optical axes; and as a consequence adjoining spectra have the order of colors reversed or otherwise different. When, in the optical examinations of thin slices, halves or alternate sectors, or alternate bands, differ as to the transmission of light, or as to color, there is evidence of a compound structure. In the polysynthetic twins of albite, labradorite, and other triclinic feldspars, if the slice cuts across the vertical axis,

parallel bands of light and darkness, or of color, indicate the multiplicity in the twinning, as the mineral is revolved on the stage. Fig. 12 (from Hawes) shows the number of such bands observed in a slice of labradorite (the fracturing is a consequence of a movement that took place in

12.

13.

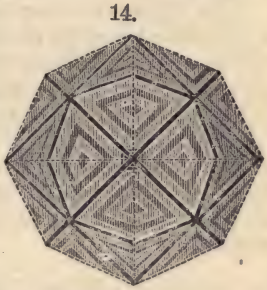


the rock after the mineral had crystallized). Fig. 13 represents the peculiar tessellation in the polysynthetic twinning of the feldspar, microcline, arising probably from the fact that the angle between the two cleavage-planes differs but 19′ from 90°.

For fuller details as to the methods of making optical investigations, see the Text-book of Mineralogy, or some other large work on the subject.

6. *Anomalies in Polarization.*—There are some isometric crystals which have the property of polarization. Examples occur in crystals of analcite, leucite, alum, boracite, fluorite, and diamond. The facts as to analcite were long since described by Sir David Brewster, and the annexed figure, indicating the arrangement of the colors or spectra in a trapezohedral crystal of this species, is from his paper. In some cases also there are variations from the isometric angles, which seem to point to a tetragonal or other form. Leucite has angles and optical characters that have led to its reference to the tetragonal system. Analogous conditions exist also in tetragonal and hexagonal crystals. The latest view is that all such irregularities are due to a molecular strain within the crystals produced at the time of their formation. It has long been known that

14.



pressure will cause the development of polarizing properties in many substances; and these are analogous cases, except that the pressure is a strain of molecular origin. Optical characters in many of the species under all the systems of crystallization vary much, and the above is a prominent source of these variations.

7. *Dichroism, Pleochroism.*—Crystals, excepting those of the isometric system, when colored, often have different colors by transmitted light, and different degrees of transparency in the directions of unequal axes at right angles to one another. In tetragonal and hexagonal crystals there may be different colors in the vertical and lateral directions; and in those under the other systems there may be different colors and transparency in three directions. Crystals of tourmaline when transparent or translucent in a direction transverse to the prism are opaque in a vertical direction, because the ordinary ray is absorbed. Zircon, which in a transverse direction is asparagus-green, is pinkish brown in a vertical, the light being differently absorbed as to its component colors in the two directions. The difference in the colors and transparency may be very slight: it is so in pyroxene and enstatite, while usually strong in hornblende and a hypersthene containing much iron. Epidote is an example of a monoclinic mineral with different colors in the three axial directions.

The different colors are best seen by polarized light, and this method may be used with very thin sections. On examining a plate of zircon cut parallel to a face of the vertical square prism, with a single nicol or tourmaline plate, the colors appear alternately as the plate or the nicol is revolved. The nicol should be first set at 0°, so that its vibration-plane coincides with the line 0° to 180° on the stage, and then the plate placed on the stage and the stage revolved; and the color thus obtained compared with that after a revolution of 90°.

5. DIAPHANEITY, LUSTRE, COLOR.

1. Diaphaneity.

Diaphaneity is the property which many objects possess of *transmitting* light; or, in other words, of permitting more or less light to pass through them. This property is

often called *transparency*, but transparency is properly one of the degrees of diaphaneity. The following terms are used to express the different degrees of this property:

Transparent—when the outlines of objects, viewed through the mineral, are distinct. Example, glass, crystals of quartz.

Subtransparent, or *semitransparent*—when objects are seen but their outlines are indistinct.

Translucent—when light is transmitted, but objects are not seen. Loaf-sugar is a good example; also Carrara marble.

Subtranslucent—when merely the edges transmit light faintly.

When no light is transmitted the mineral is described as *opaque*.

2. Lustre.

The lustre of minerals depends on the nature of their surfaces, which causes more or less light to be reflected. There are different degrees of *intensity of lustre*, and also different *kinds of lustre*.

a. The *kinds of lustre* are six, and are named from some familiar object or class of objects.

1. *Metallic*—the usual lustre of metals. Imperfect metallic lustre is expressed by the term *submetallic*.

2. *Vitreous*—the lustre of broken glass. An imperfect vitreous lustre is termed *subvitreous*. Both the vitreous and subvitreous lustres are common. Quartz possesses the former in an eminent degree; calcite often the latter. This kind of lustre may be exhibited by minerals of any color.

3. *Resinous*—lustre of the yellow resins. Example, some opal, zinc blende.

4. *Pearly*—like pearl. Example, talc, native magnesia, stilbite, etc. When united with submetallic lustre the term *metallic-pearly* is applied.

5. *Greasy*—looking as if smeared with oil. Example, elæolite, some quartz.

6. *Silky*—like silk; it is the result of a fibrous structure. Example, fibrous calcite, fibrous gypsum, and many fibrous minerals, more especially those which in other forms have a pearly lustre.

7. *Adamantine*—the lustre of the diamond. When sub-

metallic, it is termed *metallic adamantine.* Example, some varieties of white lead-ore or cerussite.

b. The *degrees of intensity* are denominated as follows:

1. *Splendent*—when the surface reflects light with great brilliancy and gives well-defined images. Example, crystals of hematite, cassiterite, some specimens of quartz and pyrite.

2. *Shining*—when an image is produced, but not a well-defined image. Example, calcite, celestite.

3. *Glistening*—when there is a general reflection from the surface, but no image. Example, talc.

4. *Glimmering*—when the reflection is very imperfect, and apparently from points scattered over the surface. Example, flint, chalcedony.

A mineral is said to be *dull* when there is a total absence of lustre. Example, chalk.

3. Color.

1. *Kinds of Color.*—In distinguishing minerals, both the external color and the color of a surface that has been rubbed or scratched, are observed. The latter is called the *streak,* and the powder abraded, the *streak-powder.*

The colors are either *metallic* or *unmetallic.*

The metallic are named after some familiar metal, as copper-red, bronze-yellow, brass-yellow, gold-yellow, steel-gray, lead-gray, iron-gray.

The unmetallic colors used in characterizing minerals are various shades of *white, gray, black, blue, green, yellow, red,* and *brown.*

There are thus snow-white, reddish-white, greenish-white, milk-white, yellowish-white.

Bluish-gray, smoke-gray, greenish-gray, pearl-gray, ash-gray.

Velvet-black, greenish-black, bluish-black, grayish-black.

Azure-blue, violet-blue, sky-blue, indigo-blue.

Emerald-green, olive-green, oil-green, grass-green, apple-green, blackish-green, pistachio-green (yellowish).

Sulphur-yellow, straw-yellow, wax-yellow, ochre-yellow, honey-yellow, orange-yellow.

Scarlet red, blood-red, flesh-red, brick-red, hyacinth-red, rose-red, cherry-red.

Hair-brown, reddish-brown, chestnut-brown, yellowish-brown, pinchbeck-brown, wood-brown.

A *play of colors*:—this expression is used when several prismatic colors appear in rapid succession on turning the mineral. The diamond is a striking example; also precious opal.

Change of colors—when the colors change slowly on turning in different positions, as in labradorite.

Opalescence—when there is a milky or pearly reflection from the interior of a specimen, as in some opals, and in cat's-eye.

Iridescence—when prismatic colors are seen within a crystal; it is the effect of fracture, and is common in quartz.

Tarnish—when the surface colors differ from the interior; it is the result of exposure. The tarnish is described as *irised* when it has the hues of the rainbow.

3. *Asterism.*—Some crystals, especially the hexagonal, when viewed in the direction of the vertical axis, present peculiar reflections in six radial directions. This arises either from peculiarities of texture along the axial portions, or from some impurities. A remarkable example of it is that of the *asteriated* sapphire, and the quality adds much to its value as a gem. The six rays are sometimes alternately shorter, indicating the rhombohedral character of the crystal.

4. *Phosphorescence.*—Several minerals give out light either by friction or when gently heated. This property of emitting light is called *phosphorescence.*

Two pieces of white sugar struck against one another give a feeble light, which may be seen in a dark place. The same effect is obtained on striking together fragments of quartz; and even the passing of a feather rapidly over some specimens of zinc-blende is sufficient to elicit light.

Fluorite is the most convenient mineral for showing phosphorescence by heat. On powdering it and throwing it on a plate of metal heated nearly to redness, the whole takes on a bright glow. In some varieties the light is emerald-green; in others, purple, rose, or orange. A massive fluor, from Huntington, Connecticut, shows beautifully the emerald-green phosphorescence. Some kinds of white marble, treated in the same way, give out a bright yellow light. After being heated for a while the mineral loses its phosphorescence; but a few electric shocks will, in many cases, to some degree restore it again.

6. ELECTRICITY AND MAGNETISM.

ELECTRICITY.—Many minerals become electrified on being rubbed, so that they will attract cotton and other light substances; and when electrified, some exhibit positive and others negative electricity when brought near a delicately suspended magnetic needle. The diamond, whether polished or not, always exhibits positive electricity, while other gems become negatively electric in the rough state, and positively only in the polished state. Some minerals, thus electrified, retain the power of electric attraction for many hours, as topaz, while others lose it in a few minutes.

Many minerals become electric when heated, and such species are said to be *pyroelectric*, from the Greek *pur*, fire, and electric.

A prism of tourmaline, on being heated, becomes polar, opposite electricity being developed in the extremities by the heat. The prisms of tourmaline have different secondary planes at the two extremities.

Several other minerals have this peculiar electric property, especially boracite and topaz, which, like tourmaline, are *hemihedral* in their modifications. Boracite crystallizes in cubes, with only the *alternate* solid angles similarly replaced (Figs. 39, 40, page 26). Each solid angle, on heating the crystals, becomes an electric pole; the angles diagonally opposite are differently modified, and have opposite polarity. Pyroelectricity has been observed also in crystals that are not hemihedral, and in many mineral species. In some cases the number of poles is more than two. In prehnite crystals a large series occur distributed over the surface.

MAGNETISM.—The name *Lodestone* is given to those specimens of an ore of iron called magnetite which have the power of attraction like a magnet; it is common in many beds of magnetite. When mounted like a horseshoe-magnet, a good lodestone will lift a weight of many pounds. This is the only mineral that has decided magnetic attraction. But several ores containing iron are *attracted* by the magnet, or, when brought near a magnetic needle, will cause it to vibrate; and moreover, the metals nickel, cobalt, manganese, palladium, platinum and osmium, have been found to be slightly magnetic.

Many iron-bearing minerals become attractable by the magnet after being heated that are not so before heating. This arises from a change of part or all of the iron to the magnetic oxide.

7. TASTE AND ODOR.

Taste belongs only to the soluble minerals. The kinds are—

1. *Astringent*—the taste of vitriol.
2. *Sweetish-astringent*—the taste of alum.
3. *Saline*—taste of common salt.
4. *Alkaline*—taste of soda.
5. *Cooling*—taste of saltpetre.
6. *Bitter*—taste of Epsom salts.
7. *Sour*—taste of sulphuric acid.

Odor is not given off by minerals in the dry, unchanged state, except in the case of a few gases and soluble minerals. By friction, moistening with the breath, the action of acids, and the blowpipe, odors are sometimes obtained which are thus designated:

1. *Alliaceous*—the odor of garlic. It is the odor of burning arsenic, and is obtained by friction, and more distinctly by means of the blowpipe, from several *arsenical* ores.

2. *Horse-radish odor*—the odor of decaying horse-radish. It is the odor of burning selenium, and is strongly perceived when ores of this metal are heated before the blowpipe.

3. *Sulphureous*—odor of burning sulphur. Friction will elicit this odor from pyrites, and heat from many sulphides.

4. *Fetid*—the odor of rotten eggs or sulphuretted hydrogen. It is elicited by friction from some varieties of quartz and limestone.

5. *Argillaceous*—the odor of moistened clay. It is given off by serpentine and some allied minerals when breathed upon. Others, as pyrargillite, afford it when heated.

III. CHEMICAL PROPERTIES OF MINERALS.

THE chemical properties of minerals are of two kinds: (1) Those relating to the chemical composition of minerals; (2) those depending on their chemical reactions, with or without fluxes, including results obtained by means of the blowpipe.

1. CHEMICAL COMPOSITION.

All the elements made known by chemistry are found in minerals, for the mineral kingdom is the source of whatever living beings—plants and animals—contain or use. A list of these elements, as at present made out, is contained in the following table, together with the symbol for each used in stating the composition of substances. These symbols are abbreviations of the Latin names for the elements. A few of these Latin names differ much from the English, as follows:

Stibium	Sb	= Antimony	Kalium	K	= Potassium
Cuprum	Cu	= Copper	Argentum	Ag	= Silver
Ferrum	Fe	= Iron	Natrium	Na	= Sodium
Plumbum	Pb	= Lead	Stannum	Sn	= Tin
Hydrargyrum	Hg	= Mercury	Wolframium	W	= Tungsten

TABLE OF THE ELEMENTS.

Aluminium	Al	27.4	Chlorine	Cl	35.5
Antimony	Sb	120	Chromium	Cr	52
Arsenic	As	75	Cobalt	Co	59
Barium	Ba	137	Copper	Cu	63.5
Beryllium	Be	13.8	Didymium	D	95
Bismuth	Bi	210	Erbium	E	166
Boron	B	11	Fluorine	F	19
Bromine	Br	80	Gallium	Ga	70
Cadmium	Cd	112	Gold	Au	197
Cæsium	Cs	133	Hydrogen	H	1
Calcium	Ca	40	Indium	In	113.4
Carbon	C	12	Iodine	I	127
Cerium	Ce	92	Iridium	Ir	198

Iron	Fe	56	Selenium	Se	79.4
Lanthanum	La	139	Silver	Ag	108
Lead	Pb	207	Silicon	Si	28
Lithium	Li	7	Sodium	Na	23
Magnesium	Mg	24	Strontium	Sr	87.6
Manganese	Mn	55	Sulphur	S	32
Mercury	Hg	200	Tantalum	Ta	182
Molybdenum	Mo	96	Tellurium	Te	128
Nickel	Ni	59	Thallium	Tl	204
Niobium(Columbium)	Nb(Cb)	94	Thorium	Th	231
Nitrogen	N	14	Thulium	Tm	170.7
Osmium	Os	199	Tin	Sn	118
Oxygen	O	16	Titanium	Ti	50
Palladium	Pd	106	Tungsten	W	184
Phosphorus	P	31	Uranium	U	240
Platinum	Pt	197	Vanadium	V	51.3
Potassium	K	39	Ytterbium	Yb	173
Rhodium	Ro	104	Yttrium	Y	91
Rubidium	Rb	85.4	Zinc	Zn	65
Ruthenium	Ru	104	Zirconium	Zr	90

Germanium is the name of another element.

The *combining weights* indicate the proportions in which the elements combine. Thus, assuming hydrogen, the lightest of the elements, to be 1, or the unit of the series, the combining weight of oxygen is 16; of iron, 56; of magnesium, 24; of sulphur, 32; and so on. When hydrogen and oxygen combine it is in the ratio of 2 pounds of hydrogen, or else 1 pound of hydrogen, to 16 pounds of oxygen, and two different compounds thus result. When oxygen and magnesium combine it is in the ratio of 16 pounds of oxygen to 24 of magnesium. Oxygen and iron combine in the ratio of 16 of oxygen to 56 of iron; or of 24 of oxygen ($1\frac{1}{2}$ times 16) to 56. Sulphur and oxygen combine in the ratio of 32 of oxygen to 32 of sulphur; or of 48 to 32 of sulphur. The combining weights are often called the *atomic* weights.

The following is the manner of using the symbols: For the compound consisting of hydrogen and oxygen in the ratio of 2 to 16, the chemical symbol is H_2O, meaning 2 of hydrogen to 1 of oxygen. (This compound is water.) For the compound of oxygen and magnesium just referred to, the symbol is MgO; for the two compounds of oxygen and iron, FeO, protoxide of iron; Fe_2O_3, sesquioxide of iron, the ratio of 1 to $1\frac{1}{2}$ being expressed by 2 to 3; for the two compounds of sulphur and oxygen, SO_2 and SO_3.

Some of the elements so closely resemble one another that their similar compounds are closely alike in crystallization and other qualities, and they are therefore said to be *isomorphous.*

This is true of iron, magnesium, calcium, and two or three other related elements. In one group of compounds of these bases, the carbonates, the crystalline form for each is rhombohedral, and among them there is a difference of less than two degrees in the angle of the rhombohedron. Besides a carbonate of calcium, a carbonate of magnesium, and a carbonate of iron, there is also a *carbonate of calcium and magnesium,* in which *half* of the calcium of the first of these carbonates is replaced by half an atom of magnesium; and another species in which the base, instead of being all magnesium, is half magnesium and half iron. By *half* is here meant half in the proportion of their combining weights.

The replacement of one of these elements by the other, and similar replacements among other groups of related elements, run through the whole range of mineral compounds. Thus we have *sodium* replacing *potassium, arsenic* replacing *phosphorus* and *antimony,* and so on.

In the combinations of oxygen and iron, as illustrated above, oxygen is combined with the iron in different proportions. FeO contains 1 of Fe (iron) to 1 of O (oxygen) and Fe_2O_3, or, as it is often written, $\dot{F}eO_3$, contains $\frac{2}{3}$ Fe to 1 of O. As the iron in each of these cases satisfies the oxygen, it is evident that the iron must be in two different states, (1) a *protoxide* state, and (2) a *sesquioxide* state. One part of iron in this sesquioxide state ($= \frac{2}{3}$Fe) often replaces in compounds one part of iron in the protoxide state (or 1Fe), with no greater change of qualities than happens in the replacement of iron by magnesium, or calcium, explained above; or, avoiding fractions, 3 parts of Fe in the protoxide state replaces 2Fe in the sesquioxide state. Writing $\dot{F}e$ for the last 2Fe, the statement becomes 1 of Fe_3 replaces 1 of $\dot{F}e$. Aluminium occurs only in the sesquioxide state, and the ordinary symbol of the oxide is Al_2O_3, or $\dot{A}lO_3$. But it is closely related to iron in the sesquioxide state, so that, using the same mode of expression as for iron, 1 of $\dot{A}l$ replaces 1 of Fe_3, or 1 of Mg_3, and so on. Similarly, writing R for any metal, 1 of $\dot{R}$ replaces 1 of R_3. Again, in potash (K_2O), soda (Na_2O), lithia (Li_2O),

water (H_2O), one of oxygen (O) is combined severally with 2 of K (potassium), of Na (sodium), of Li (lithium), of hydrogen; and hence 2K, 2Na, 2Li, that is, K_2, Na_2, Li_2, may each replace in compounds 1Ca, or 1Mg, etc.

The elements *potassium, sodium, lithium, hydrogen,* of which it takes two parts to combine with 1 of oxygen, are called monads. Other elements of the group of monads are *rubidium, cæsium, thallium, silver,* and also *fluorine, chlorine, bromine, iodine.* Still other elements combining by two parts in their oxygen or sulphur compounds, etc., are nitrogen, phosphorus, antimony, boron, niobium, tantalum, vanadium and gold. For example, for arsenic there are the compounds As_2S, As_2S_3, As_2O_3, As_2O_5, etc. Another characteristic of these elements of the hydrogen, sodium, chlorine, and arsenic groups is that the number of equivalents of the acidic element in the compounds into which they enter is, with a rare exception, *odd,* and of the 1, 3, 5, etc., series, and on this account they are called in chemistry *perissads;* while the other elements, in whose compounds their number is of the 1, 2, 3, etc. (or 2, 4, 6) series, are called *artiads.* An apparent exception exists under the artiads in the sesquioxides, but this does not alter the general character of the series.

The facts above cited sustain the general statement that Ca_2, Mg_2, Mn_2, Zn_2, Fe_2, Al, Fe, Mn, have equivalent combining values, and hence in minerals often replace one another; and so also Ca, Mg, Mn, Zn, Fe, K_2, Na_2, Li_2, H_2, may replace one another. Similarly, also, As_2, or Sb_2, replaces S in some minerals.

With reference to the classification of minerals the elements may be conveniently divided into two groups: (1) the *Acidic,* and (2) the *Basic.* The former includes oxygen and the elements which were termed the *acidifiers* and *acidifiable* elements in the old chemistry. They are those which have been called in mineralogy the *mineralizing* elements, since they are the elements which are found combined with the metals to make them ores, that is, to mineralize them. The basic are the rest of the elements. The groups overlap somewhat, but this need not be dwelt upon here.

The more important of the acidic elements are the following: oxygen, fluorine, chlorine, bromine, iodine, sulphur, selenium, tellurium, boron, chromium, molybdenum,

tungsten, phosphorus, arsenic, antimony, vanadium, nitrogen, tantalum, niobium, carbon, silicon.

Again, among the conpounds of these elements occurring in the mineral kingdom there are two grand divisions, the *binary* and the *ternary*. The binary consist of one or more elements of each of the acidic and basic divisions, and the ternary of one or more elements of each of these two classes, along with oxygen, fluorine, or sulphur as a third. The binary include the *sulphides, arsenides, chlorides, fluorides, oxides,* etc., and the ternary the *sulphates, chromates, borates, arsenates, phosphates, silicates, carbonates,* etc., and also the *sulph-arsenites* and *sulph-antimonites,* in which a basic metal (usually lead, copper, silver) is combined with arsenic or antimony and sulphur.

The following are examples of the symbols of binary and ternary compounds:

1. *Binary.*

1. *Sulphides, Selenides.*—Ag_2S = silver sulphide; Ag_2Se = silver selenide; PbS = lead sulphide; ZnS = zinc sulphide; FeS_2 = iron disulphide.

2. *Fluorides, Chlorides,* etc.—CaF_2 = calcium fluoride; AgCl = silver chloride; AgBr = silver bromide; AgI = silver iodide; NaCl = sodium chloride (common salt).

3. *Oxides.*—$Al_2O_3 = 3(Al_{\frac{2}{3}}O)$ = aluminium sesquioxide; As_2O_3 = arsenic trioxide; As_2O_5 = arsenic pentoxide; BaO = barium oxide; Be_2O_3 = beryllium oxide; B_2O_3 = boron trioxide (boracic acid); CaO = calcium oxide (lime); CeO = ceria; CO_2 = carbon dioxide (carbonic acid); CrO_3 = chromium trioxide (chromic acid); Cu_2O = copper suboxide; CuO = copper oxide; DiO = didymia; H_2O = hydrogen oxide (water); FeO = iron oxide; Fe_2O_3 = iron sesquioxide; PbO = lead oxide; Li_2O = lithium oxide; MgO = magnesium oxide; MnO = manganese oxide; Mn_2O_3 = manganese sesquioxide; MnO_2 = manganese dioxide; P_2O_5 = phosphorus pentoxide; K_2O = potassium oxide; SiO_2 = silicon dioxide (silica); Na_2O = sodium oxide; SrO = strontium oxide; SO_2 = sulphur dioxide (sulphurous acid); SO_3 = sulphur trioxide; SnO_2 = tin dioxide; Tm_2O_3 = thulia; V_2O_5 = vanadium pentoxide (vanadic acid); WO_3 = tungsten trioxide (tungstic acid);

Yb_2O_3 = ytterbia; ZnO = zinc oxide; ZrO_2 = zirconium dioxide.

The composition of these compounds may be obtained from the table of combining weights, page 86. For example, with reference to the first of them (Ag_2S), the table gives for the combining weight of silver (Ag), 108, and for that of sulphur, 32. The elements exist in the compound therefore in the proportion of 216 to 32, and from it the composition of a hundred parts is easily deduced.

If the formula were (Ag_2, Pb)S, signifying a silver-and-lead sulphide, and if the silver and lead were in the ratio of 1 to 1, then once the combining weight of silver is taken; that is, 108, and half the atomic weight of lead, which is 103·5; and the sum of these numbers, with 32 for the sulphur, expresses the ratio of the three ingredients.

For Al_2O_3 we find the combining weight of aluminium 27·4; doubling this for Al_2 makes 54·8. Again, for oxygen, we find 16; and three times 16 is 48. 54·8 to 48 is therefore the ratio of aluminium to the oxygen in Al_2O_3, from which the percentage proportion may be obtained.

2. *Ternary Oxygen Compounds.*

Silicates.—Of these compounds there are two prominent groups. In one of these groups the general formula is RO_3Si, and in the other R_2O_4Si. In both of these formulas, R stands for any basic elements in the protoxide state, as Ca, Mg, Fe, etc., either alone or in combination. If the basic element is Mg (magnesium) they become MgO_3Si, and MgO_2Si (sometimes also written $MgO + SiO_2$ and $2MgO + SiO_2$, this being the *old* style). In the first of these formulas the combining values of the basic element R and the acidic element or silicon, as measured by their combinations with oxygen, are in the proportion of 1 to 2, for R stands for an element in the *protoxide* state, while Si stands for silicon, which is in the *dioxide* state, its oxide being a dioxide; and hence the minerals so constituted are called *Bisilicates.* In the second of these formulas this ratio is 2 to 2, or 1 to 1, and hence these are called *Unisilicates.* The second style of formula (the old style) has the advantage of expressing the bases and acids obtained in an analysis and mentioned in the tables of percentage results

Multiplying these formulas by 3, they become $R_3O_9Si_3$, and $(2R_3)O_{12}Si_3$; and the same composition is expressed. In this form the substitution of sesquioxide bases for protoxide may be indicated: thus, $R_3RO_{12}Si_3$ signifies that half of the $2R_3$ is replaced by Al or Fe, or some other element in the sesquioxide state.

There are also some species in which the ratio is 1 to less than 1, and these are called *Subsilicates.*

The ratio here referred to is the oxygen ratio or the *quantivalent ratio.*

The other ternary compounds require no special remarks in this place.

2. Chemical Reactions.

1. *Trials in the wet way.*

1. *Test for Carbonates.*—Into a test-tube put a little hydrochloric acid diluted with one half water, and add a small portion in powder of the mineral. With a carbonate, there will be a brisk effervescence caused by the escape of carbonic dioxide (carbonic acid), when heat is applied, if not before. With calcium carbonate no heat or pulverization is necessary.

2. *Test for Gelatinizing Silica.*—Some silicates, as nephelite and many zeolites, when powdered and treated with strong hydrochloric acid, are decomposed, and deposit the silica in the state of a jelly. The experiment may be performed in a test-tube, or small glass flask. Sometimes the evaporation of the liquid nearly to dryness is necessary in order to obtain the jelly. Some silicates do not afford the jelly unless they have been previously ignited before the blowpipe, and some gelatinizing silicates lose the power on ignition.

Test for Soda in some Silicates.—When nephelite is treated with hydrochloric acid the solution deposits, on evaporation, cubes of common salt (sodium chloride); and in this and some other sodium silicates, if the hydrochloric solution is treated with a concentrated solution of uranium acetate, yellow tetrahedrons of sodium uranate are formed.

3. *Decomposability of Minerals by Acids.*—To ascertain whether a mineral is decomposable by acids or not, it is very finely powdered and then boiled with strong hydro-

chloric acid, or, in case of many metallic minerals, with nitric acid. In some cases (as leucite, scapolite, labradorite, etc.), where no jelly is formed, there is a deposit of silica in a pulverulent state. With the sulphides and nitric acid there is often a deposit of sulphur, which usually floats upon the surface of the fluid as a dark spongy mass; with hydrochloric acid and some sulphides, sulphuretted hydrogen is given off. Some oxides, and also some sulphates and many phosphates, are soluble entirely without effervescence. But many minerals resist decomposition with nitric acid as well as hydrochloric. It is sometimes difficult to tell whether a mineral is decomposed with the separation of the silica or whether it is unacted upon. In such a case a portion of the clear fluid is neutralized by soda (sodium carbonate), and if anything has been dissolved it will usually be precipitated.

4. *Test for Lime in Apatite.*—A solution of apatite in hydrochloric acid, if treated with sulphuric acid, deposits gypsum freely.

5. *Test for Titanium in Menaccanite.*—The pulverized mineral, heated with hydrochloric acid, is slowly dissolved; the yellow solution, filtered from the undecomposed mineral and boiled with the addition of tin-foil, assumes a beautiful blue or violet color—a result not obtained with hematite, the mineral it most resembles.

6. *Test for Fluorine.*—Most fluorides (as fluorite, cryolite, etc.) are decomposed by strong heated sulphuric acid, and give out fluorine which will etch a glass plate in reach of the fumes. The trial may be made in a lead cup, and the glass put over it as a loose cover.

7. *Test for Native Iron.*—Dilute nitrate of copper deposits copper on a clean plate of iron.

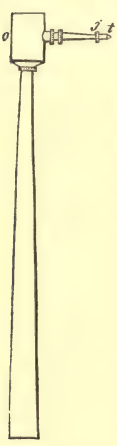
8. *Test for Phosphoric Acid in Apatite,* etc.—A concentrated nitric-acid solution of ammonium molybdate acts on apatite and deposits yellow octahedrons or dodecahedrons of ammonium phosphomolybdate; and a drop of the solution will produce this result with the apatite of a thin section prepared for microscopic study.

2. *Trials with the Blowpipe.*

The blowpipe, in its simplest form, is merely a bent tube of small size, eight to ten inches long, terminating at one

end in a minute orifice. It is used to concentrate the flame on a mineral, and this is done by blowing through it while the smaller end is just within the flame.

The annexed figure represents the form commonly employed, except that it often has a trumpet-shaped mouthpiece. It contains an air-chamber (*o*) to receive the moisture which is condensed in the tube during the blowing; the moisture, unless thus removed, is often blown through the small aperture and interferes with the experiment. The jet, *jt*, is movable, and it is desirable that it should be made of platinum, in order that it may be cleaned when necessary, either by high heating or by immersion in an acid.



In using the blowpipe it is necessary to breathe and blow at the same time, that the operator may not interrupt the flame in order to take breath. Though seemingly absurd, the necessary tact may easily be acquired. Let the student first breathe a few times through his nostrils while his cheeks are inflated and his mouth closed. After this practice let him put the blowpipe to his mouth and he will find no difficulty in breathing as before while the muscles of the inflated cheeks are throwing the air they contain through the blowpipe. When the air is nearly exhausted the mouth may again be filled through the nose without interrupting the process of blowing.

The flame of a candle, or a lamp with a large wick, may be used; and when so, it should be bent in the direction the flame is to be blown. But it is far better, when gas can be had, to use a Bunsen's burner.

The flame has the form of a cone, yellow without and blue within. The heat is most intense just beyond the extremity of the blue flame. In some trials it is necessary that the air should not be excluded from the mineral during the experiment, and when this is the case the *outer* flame is used. The outer is called the *oxidizing* flame (because oxygen, one of the constituents of the atmosphere, combines in many cases with some parts of the assay, or substance under experiment), and the inner the *reducing* flame. In the latter the carbon and hydrogen of the flame, which are in a high state of ignition, and which are enclosed from

the atmosphere by the outer flame, tend to unite with the oxygen of any substance that is inserted in it. Hence substances are reduced in it.

The mineral is supported in the flame either on charcoal; or by means of steel forceps (as in the annexed figure) with

platinum extremities (*ab*), opened by pressing on the pins *p p*; or on platinum wire or foil.

To ascertain the *fusibility* of a mineral, the fragment for the platinum forceps should not be larger than the head of a pin, and, if possible, should be thin and oblong, so that the extremity may project beyond the platinum. The fusible metals alloy readily with platinum. Hence compounds of lead, arsenic, antimony, etc., must be guarded against. These compounds are tested on charcoal. The forceps should not be used with the fluxes, but instead either charcoal or the platinum wire or foil.

The *charcoal* should be firm and well burnt; that of soft wood is the best. It is employed especially for the reduction of oxides, in which the presence of carbon is often necessary, and also for observing any substances which may pass off and be deposited on the charcoal around the assay. These coatings are usually oxides of the metals, which are formed by the oxidation of the volatile metals as they issue from the reduction-flame.

The platinum wire is employed in order to observe the action of the fluxes on the mineral, and the colors which the oxides impart to the fluxes when dissolved in them. The wire used is No. 27. This is cut into pieces about three inches long, and the end is bent into a small loop, in which the flux is fused. This makes what is called a bead. When the experiment is complete the beads are removed by uncoiling the loop and drawing the wire through the fingernails. After use for awhile the end breaks off, because platinum is acted upon by the soda, and then a new loop has to be made. Dilute sulphuric acid will remove any of the flux that may remain upon it after a trial has been made.

Glass tube is employed for various purposes. It should be from a line to a fourth of an inch in bore. It is cut into

pieces four to six inches long, and used in some cases with both ends open, in others with one end closed. In the *closed* tube, either heated directly over the Bunsen burner, or with the aid of the blowpipe, volatile substances in the assay are vaporized and condensed in the upper colder part of the tube, where they may be examined by a lens if necessary, or by further heating. The odor given off may also be noted; also the acidity of any fumes by inserting a small strip of litmus paper in the mouth of the tube, for acids redden litmus paper. The closed tube is used to observe all the effects that may take place when a substance is heated out of contact with the air. In the *open* tube the atmosphere passes through the tube in the heating, and so modifies the result. The assay is placed an inch or an inch and a quarter from the lower end of the tube; the tube should be held nearly horizontally, to prevent the assay from falling out. The strength of the draught depends upon the inclination of the tube, and in special cases it should be inclined as much as possible.

The most common *fluxes* are *borax* (sodium biborate), *salt of phosphorus* (sodium and ammonium phosphate), and *soda* (sodium carbonate, either the carbonate or bicarbonate of soda of the shops). These substances, when fused and highly heated, are very powerful solvents for metallic oxides. They should be pure preparations. The borax and soda are much the most important. In using the platinum wire, the loop may be highly heated, and then a portion of the borax or soda may be taken up by it, and by successive repetitions of this process the requisite amount of the flux may be obtained on the wire. Then, by bringing the melted flux of the loop into contact with one or more grains of the pulverized mineral, the assay is made ready for the trial. With soda and quartz a perfectly clear globule is obtained, cold as well as hot, if the flux is used in the right proportion. Some oxides impart a deep and characteristic color to a bead of borax. In other cases the color obtained is more characteristic when salt of phosphorus is employed. The color obtained in the outer flame is often different from that which is obtained in the inner flame. The beads are sometimes transparent and sometimes opaque. If too much substance is employed the beads will be opaque when it is desired that they should be transparent, and in such cases the experiment should be re-

peated with less substance. In many cases pulverized mineral and the flux, a little moistened, are mixed together into a ball upon charcoal, especially in the experiments with soda.

In the examination of sulphides, arsenides, antimonides and related ores, the assay should be *roasted* before using a flux, in order to convert the substance into an oxide. This is done by spreading the substance out on a piece of charcoal and exposing it to a gentle heat in the oxidizing flame. The sulphur, arsenic, antimony, etc. then pass off as oxides in the form of vapors, leaving the non-volatile metals behind as oxides. The escaping sulphurous acid gives the ordinary odor of burning sulphur; arsenous acid, from arsenic present, the odor of garlic, or an alliaceous odor; selenous acid, from selenium present, the odor of decaying horse-radish; while antimony fumes are dense white, and have no odor.

The following is the *scale of fusibility* which has been adopted, beginning with the most fusible:

1. STIBNITE.—Fusible in large pieces in the candle flame.
2. NATROLITE.—Fusible in small splinters in the candle flame.
3. ALMANDINE, or bright-red GARNET.—Fusible in large pieces with ease in the blowpipe flame.
4. ACTINOLITE.—Fusible in large pieces with difficulty in the blowpipe flame.
5. ORTHOCLASE, or common feldspar. Fusible in small splinters with difficulty in the blowpipe flame.
6. BRONZITE. Scarcely fusible at all.

The *color of the flame* is an important character in connection with blowpipe trials. When the mineral contains *sodium* the color of the flame is deep yellow, and this is generally true in spite of the presence of other related elements. When sodium (or soda) is absent, *potassium* (or potash) gives a pale violet color; *calcium* (or lime) a pale reddish yellow; *lithium*, a deep purple-red, as in lithiamica; *strontium*, a bright red, this element being the usual source of the red color in pyrotechny; *copper*, emerald green; *phosphates*, bluish green; *boron*, yellowish green; *copper chloride*, azure-blue. Beads should be examined by daylight only, and should be held in such position that the color is not modified by green trees or other bright objects when examined by transmitted light. Colored flames are

seen to best advantage when some black object is beyond the flame in the line of vision.

It is also to be noted, in the trials, whether the assay heats up quietly or with decrepitation; whether it fuses with effervescence or not, or with intumescence or not; whether it fuses to a bead which is transparent, clouded, or opaque; whether blebby (containing air-bubbles) or not; whether scoria-like or not.

Testing for Water.—The powdered mineral is put at the bottom of a closed glass tube, and after holding the extremity for a moment in the flame of a Bunsen's burner, moisture, if any is present, will have escaped and be found condensed on the inside of the tube, above the heated portion. Litmus or turmeric paper is used to ascertain if the water is acid or alkaline, acids changing the blue of litmus paper to red, and alkalies the yellow of turmeric paper to brown.

Testing for an Alkali.—If the fragment of a mineral, heated in the platinum forceps, contains an alkali, it will often, after being highly heated, give an alkaline reaction when placed, after moistening, on turmeric paper, turning it brown. This test is applicable to those salts which, on heating, part with a portion of their acid and are rendered caustic thereby. Such are the carbonates, sulphates, nitrates, and chlorides of the alkaline metals.

Testing for Alumina or Magnesia.—Cobalt nitrate, in solution, is used to distinguish an infusible and colorless mineral containing aluminium from one containing magnesium. A fragment of the mineral is first ignited, and then wet with a drop or two of the cobalt solution and heated again. The aluminium mineral will assume a blue color, and the magnesium mineral a pale red or pink.

Any fusible silicate, when moistened with cobalt nitrate and ignited, will assume a blue color, hence this test is only decisive in testing infusible substances.

Infusible *zinc* compounds, when moistened with cobalt nitrate, assume a green color.

Testing for Lithium.—Some lithium minerals give the bright purple-red flame if simply heated in the platinum forceps. In other cases mix the powdered mineral with one part of fluorite and one of potassium bisulphate. Make the whole into a paste with a little water, and heat it on the platinum wire in the blue flame.

Testing for Boron.—When the bright yellow-green of boron is not obtained directly on heating the mineral containing it, one part of the powdered mineral should be mixed with one part of powdered fluorite and three of potassium bisulphate; and then treated as in the last. The green color appears at the instant of fusion.

Testing for Fluorine.—To detect fluorine in fluorides mix a little of the powdered substance with potassium bisulphate, put the mixture in a closed glass tube and fuse gently. The bisulphate gives off half of its sulphuric acid at a high temperature, which acts powerfully on anything it can attack. If a fluoride is present, hydrofluoric acid will be given off, and the walls of the tube will be found roughened and etched when the tube is broken open and cleaned after the experiment. If a silicate containing fluorine be powdered and mixed with previously fused salt of phosphorus, and heated in the open tube by blowing the flame into the lower end of the tube, hydrofluoric acid is given off, and the tube is corroded just above the assay.

Silicates.—Nearly all silicates undergo decomposition with salt of phosphorus, setting free the silica, forming a bead which is clear while hot and has a skeleton of silica floating in it. The bead is sometimes clear also when cold.

Iron.—Minerals containing much iron produce a magnetic globule when highly heated. Usually the reducing flame is required, and sometimes the use of soda. With borax iron gives a bead with the oxidizing flame which is yellow while hot, but colorless on cooling, and which in the reducing flame becomes bottle-green.

Cobalt.—Minerals containing cobalt afford, with borax, a beautiful blue bead. If sulphur or arsenic is present it should be first roasted off on charcoal.

Nickel.—In the oxidizing flame with borax, the bead is violet when hot, and red-brown on cooling. In the reducing flame the glass becomes gray and turbid from the separation of metallic nickel, and on long blowing, colorless. The reaction is obscured by the presence of cobalt, iron, and copper.

Manganese.—With borax in the oxidizing flame, the bead is a deep violet-red, and almost black if too much of the mineral is used. To see the color, examine by transmitted light. With soda in the same flame the opaque bead is bluish green.

Chromium.—With borax, both in the oxidizing and reducing flame, the bead is bright emerald-green.

Titanium.—Titanium oxide with salt of phosphorus on platinum wire in O.F. dissolves to a clear glass, which, if much is present, becomes yellow, while hot and colorless on cooling; but in R.F. the hot globule obtained in O.F. reddens and assumes finally a beautiful violet color. On charcoal with tin the glass becomes violet if there is not too much iron present.

Zinc.—Zinc and some of its compounds when heated cover the charcoal with zinc oxide, which is yellow while hot, but white on cooling; and this coating, if wet with cobalt solution and then heated, assumes a fine yellowish green color which is most distinct when cold.

Lead, copper, tin, silver, when characterizing a mineral, give with soda in the reducing flame minute metallic globules, which are malleable, or may be cut with a knife; they can be distinguished by their well-known physical properties. When two or more of these metals occur together, or iron is also present, the globules consist usually of an alloy of the metals.

Lead.—When the mineral is treated with soda on charcoal in the oxidizing flame, the yellow oxide coats the charcoal around the assay.

Copper.—The flame is colored, in most cases, bright green. With borax or salt of phosphorus in the reducing flame the bead is red. In the oxidizing flame the bead is green when hot, and becomes blue or greenish blue on cooling.

Mercury.—Heated in the closed tube with soda, a sublimate of metallic mercury covers the inside of the tube.

Silver.—If the silver is in very small quantities, as in argentiferous galena, the assay is put into a little cup made of bone-ashes (bone burnt white and finely pulverized), and subjected to the oxidizing flame; the lead is oxidized and sinks into the bone-ashes, leaving the silver a brilliant globule on the cupel. Before cupellation it is often necessary to melt the assay together with some borax and pure lead in a hole on charcoal. By this process the sand and impurities are removed, and a globule of lead is obtained which contains all the silver, and which may be separated from the slag and be oxidized as above.

Arsenic.—In the closed tube arsenic sublimes and coats

the tube with brilliant grains, or a crust, of metallic arsenic. If the mineral contains sulphur as well as arsenic, sublimates of the yellow and red arsenic sulphides (orpiment and realgar) are often formed. In the open tube a sublimate of white arsenous acid is formed, which condenses in bright crystals on the walls of the tube, and a strong garlic odor is given off. On charcoal the alliaceous odor is at once perceptible.

Antimony.—In the closed tube, when sulphur is present, the assay yields a sublimate which is black when hot, brown-red when cold. In the open tube dense white vapors are given off and a white *amorphous* sublimate covers the inside of the tube, which, for the most part, does not volatilize when reheated. On charcoal the assay yields dense, white, inodorous fumes.

Tellurium.—In the open tube a white or grayish sublimate is obtained, which may be fused to *clear, colorless drops*. On charcoal a white coating is produced, and the reducing flame is colored green.

Sulphur.—All sulphates and other sulphur-bearing minerals, when heated on charcoal with soda, produce a dark, yellowish-brown sulphide of sodium; and if a fragment of this is moistened and placed on a polished plate of silver, it turns it immediately brownish black, or black. Pure soda, and a flame wholly free from sulphur, is needed for the trial, since the least trace of sulphur in either vitiates the result. Many sulphides give fumes of sulphur on charcoal. The higher sulphides afford these fumes in a closed tube. The others afford fumes of sulphurous acid in an open tube, which redden a moistened blue litmus paper placed in the upper end of the tube.

Selenium.—Selenium and many selenides afford a steel-gray sublimate in an open tube, which at the upper edge appears red. On charcoal brown fumes are given off with an odor like that of decaying horse-radish.

Chlorides.—If a bead of borax be saturated with copper oxide, and then dipped into the powder of a substance which is to be tested for chlorine, a chloride of copper is formed which imparts an azure-blue color to the flame if any chlorine is present. If dissolved in water or nitric acid a little silver nitrate produces a dense white precipitate of silver chloride.

Nitrates.—A nitrate, if fused on charcoal, will deflagrate

with brilliancy, owing to the decomposition of the nitrate and the union of its oxygen with the carbon.

Phosphates.—Phosphates give a dirty green color to the blowpipe flame. The color is more distinct if the substance is first moistened with sulphuric acid. If a phosphate is pulverized and heated in a closed glass tube with some bits of magnesium wire, the phosphoric acid is reduced; and when the fusion is moistened with water the very disagreeable odor of phosphuretted hydrogen is obtained.

For a full account of blowpipe reactions recourse should be had to a treatise on the blowpipe. The best American works on the subject are Prof. G. J. Brush's "Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis," and H. B. Cornwall's "Manual of Blowpipe Analysis."

In the description of species beyond, the following abbreviations are used in speaking of blowpipe reactions:

B.B. = before the blowpipe; *O.F.* = oxidizing flame; *R.F.* = reducing flame.

IV. DESCRIPTIONS OF MINERALS.

CLASSIFICATION.

SOME of the prominent points in the classification of minerals adopted in the following pages are given in connection with the remarks on chemical composition, page 79.

Many instructors in the science, and most of those who consult a work on Mineralogy for practical purposes, prefer an arrangement of the ores which groups them under the head of the metal prominent in their constitution. The method of grouping mineral species according to the basic element has therefore been here, to a large extent, followed. An exception has been made in the case of the silicates, because it is with them almost impracticable, on account of the number of basic elements they often contain; and, moreover, not more than half a dozen useful ores exist among them. The silicates therefore, which include the larger part of all minerals, make together one of the grand divisions in the classification, and they are presented according to their natural groups, in the same order as in the larger mineralogy.

The prominent subdivisions in the classification are as follows;

I. THE ACIDIC DIVISION, including the acidic elements occurring native, and the native compounds of the acidic elements with one another.

II. THE BASIC DIVISION, including the basic elements occurring native, and the native binary and ternary compounds of the basic elements—the silicates excepted.

III. SILICA and the SILICATES.

IV. THE HYDROCARBON COMPOUNDS, including mineral oils, resins, wax, and coals.

The following are the chief subdivisions under these heads:

I. ACIDIC DIVISION.

1. Sulphur Group.—The chief oxide a trioxide, its formula RO_3. Includes Sulphur and sulphur oxides; Tel-

lurium and tellurium oxides; Molybdenum sulphide and oxide; Tungsten oxide.

2. Boron Group.—The chief oxide a trioxide, its formula R_2O_3. Includes compounds of Boron with oxygen.

3. Arsenic Group.—The chief oxide a pentoxide, its formula R_2O_5. Includes Arsenic and arsenic sulphides and oxides; Antimony and antimony sulphide, arsenide and oxides; Bismuth and bismuth sulphide, telluride and oxide.

4. Carbon Group.—The chief oxide a dioxide, its formula RO_2. Includes Carbon (Diamond, Graphite) and carbon dioxide. (Quartz, SiO_2, belongs here chemically, but is placed with the Silicates.)

II. Basic Division.

Gold; Silver; Platinum and Iridium; Palladium; Quicksilver; Copper; Lead; Zinc; Cadmium; Tin; Titanium; Cobalt and Nickel; Uranium; Iron; Manganese; Aluminium; Cerium, Yttrium, Lanthanum, Didymium and Erbium; Magnesium; Calcium; Barium and Strontium; Potassium and Sodium; Ammonium; Hydrogen.

III. Silica and Silicates.

1. Silica.
2. Anhydrous Silicates.
    1. Bisilicates.
    2. Unisilicates.
    3. Subsilicates.
3. Hydrous Silicates.
    1. General section of Hydrous Silicates.
    2. Zeolite section.
    3. Margarophyllite section.

IV. Hydrocarbon Compounds.

1. Oils, Resins, Wax.
2. Asphaltum, Coals.

General Remarks on Ores.

An ore, in the mineralogical sense of the word, is a mineral compound in which a metal is a prominent constituent. In the miner's use of the term it is a mineral substance that yields, by metallurgical treatment, a valuable

metal, and especially when it profitably yields such a metal. In the former sense, galena, the common ore of lead, is, if it contains a little silver, an *argentiferous* lead-ore; while, in the latter, if there is silver enough to make its extraction profitable, it is a silver-ore. Further than this, where a native metal, or other valuable metallic mineral, is distributed intimately through the gangue, the mineral and gangue together are often called the ore of the metal it produces.

We have beyond to do with ores only in the mineralogical sense.

Ores are compounds of the metals, not metals in the native state. The more common kinds are compounds of the metals with *Sulphur* (sulphides); with *Arsenic* (arsennides); with *Sulphur* and *Arsenic* (sulph-arsenides); with sulphur in ternary combination along with arsenic, antimony or bismuth (making compounds called sulph-arsenites, sulph-antimonites, sulpho-bismutites); with *Selenium* (selenides); with *Tellurium* (tellurides); with *Oxygen* (oxides); with *Chlorine, Iodine,* or *Bromine* (chlorides, iodides, or bromides); with oxygen in ternary combination with carbon (making carbonates); with *Sulphur* (making sulphates); with *Arsenic* (making arsenates); with *Phosphorus* (making phosphates); with *Silicon* (making silicates).

Gold and platinum are, with rare exceptions, found only native, or intimately mixed in essentially the pure state with some metallic minerals. Tellurium is the only acidic element that occurs combined with gold in nature.

Silver is found in the state of sulphide, antimonide, selenide, telluride, sulph-arsenites and sulph-antimonites, but never as oxide or in oxygen ternary compounds.

Quicksilver occurs in the state of sulphide (the common ore); also in that of selenide and sulph-arsenites.

Copper and lead occur in the state of sulphides (common ores), and also in all the binary and ternary states mentioned above.

Zinc is known in the state of sulphide (very common), oxide, carbonate, sulphate, silicate (all, excepting the sulphate, valuable as ores); and *Cadmium* in that of sulphide only.

Tin occurs in the state of oxide (the common ore) and sulphide.

Cobalt and *Nickel* occur in the states of sulphide, arsenide, sulph-arsenides, antimonide, oxide, sulphate, arsenate, carbonate; and nickel in that also of a silicate.

Iron occurs in the state of sulphide (very common, but not useful as an ore of iron); of arsenide, sulph-arsenide; of oxide (the common ores of iron); carbonate (useful ore), sulphate, arsenate, phosphate, silicate.

Manganese occurs in the state of sulphide (rare), arsenide (rare), oxide (the common ores), carbonate, sulphate, phosphate, silicate.

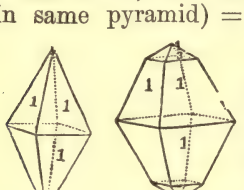
I. MINERALS CONSISTING OF THE ACIDIC ELEMENTS.

Oxygen might properly be included in this section, since it occurs native in the atmosphere mixed with nitrogen, constituting 21 per cent of it. But this mention of it is all that is necessary. The ternary compounds, in which, as in sulphuric acid, hydrogen is the basic element, are here included. Chlorine, bromine, and iodine do not occur native, and neither do their oxides, nor any compounds with acidic elements, and hence these elements are not represented under this division. The same is true of selenium and chromium of the sulphur group, and of vanadium, tantalum, and niobium of the arsenic group.

1. SULPHUR GROUP.

Native Sulphur.

Orthorhombic. In acute octahedrons, and secondaries to this form, with imperfect octahedral cleavage; $1 \wedge 1$ (in same pyramid) $= 106° 25'$ and $85° 07'$; $1 \wedge 1$ (over base) $= 143° 23'$. Also massive.



Color and streak sulphur-yellow, sometimes orange-yellow. Lustre resinous. Transparent to translucent. Brittle. H. $= 1.5 - 2.5$. G. $= 2.07$. Burns with a blue flame and sulphurous odor. In a closed tube wholly volatilized and redeposited on the walls of the tube.

Native sulphur is often contaminated with clay or bitu-

men. Sometimes contains selenium, and has then an orange-yellow color.

Diff. It is easily distinguished by its burning with a blue flame, and the sulphur odor then afforded.

Obs. The great repositories of sulphur are either beds of gypsum and the associate rocks, or the regions of active or extinct volcanoes. In the valley of Noto and Mazzaro in Sicily, at Conil near Cadiz in Spain, Bex in Switzerland, and Cracow in Poland, it occurs in the former situation. Sicily and the neighboring volcanic islands, Vesuvius and the Solfatara in its vicinity, Iceland, Teneriffe, Java, Hawaii, New Zealand, Deception Island, and most active volcanic regions, afford more or less sulphur.

On the Potomac, twenty-five miles above Washington, sulphur has been found associated with calcite in a gray compact limestone; sparingly about springs where hydrogen sulphide is evolved, in New York and elsewhere; in cavities where iron sulphides have decomposed, and in many coal-mines. Abundant near Clear Lake, in California; Inferno, Humboldt County, and Rabbit Hole Mines, Nevada; near Evanston, Wyoming; in Utah, Idaho, etc.

The native sulphur of commerce is brought largely from Sicily, where it occurs in beds along the central part of the south coast and to some distance inland. It undergoes rough purification by fusion before exportation, which separates the earth and clay with which it occurs.

Sulphur when cooled from fusion, or above 232° F., crystallizes in *oblique* rhombic prisms. When poured into water at a temperature above 300° F. it acquires the consistency of soft wax, and is used to take impressions of gems, medals, etc., which harden as the sulphur cools. The uses of sulphur for gunpowder, bleaching, the manufacture of sulphuric acid (which is the chief use), and also in medicines, are well known. Sulphur occurs in various ores as sulphides and sulphates, Among the sulphides are *pyrite*, *marcasite* and *pyrrhotite*, iron sulphides; *galena*, a lead sulphide, the common ore of lead; *chalcopyrite*, or yellow copper-ore, a copper and iron sulphide; *cinnabar*, a mercury sulphide; *argentite*, a silver sulphide, etc.

Sulphuric and Sulphurous Acids.

Sulphuric acid is occasionally met with around volcanoes, and it is also formed from the decomposition of hydrogen sulphide about sulphur springs.

It is intensely acid. *Composition,* Sulphur trioxide (SO_3) 81.6, water 18.4 = 100, it being chemically *hydrogen sulphate.* Occurs in the waters of Rio Vinagre, South America; in Java; in Genesee Co., N. Y., at Tuscarora; St. Davids, and elsewhere, Canada West.

Manufactured from sulphur, and also from the common sulphides, especially pyrite.

Sulphurous acid, or sulphur dioxide (SO_2), is produced when sulphur burns, and causes the odor perceived during the combustion of mineral coal. Common about active volcanoes. It destroys life and extinguishes combustion. *Composition,* Sulphur 50.00, oxygen 50.00.

Native Tellurium.

Rhombohedral; R $\wedge$ R = 86° 57′. Occurs sometimes in six-sided prisms with perfect *lateral* cleavage; but is commonly granular massive. Color and streak tin-white. Brittle. H. = 2–2.5. G. = 6.1–6.3.

Sometimes contains a little iron, and also a trace of gold. In an open tube, B.B. yields a white inodorous sublimate, which may be fused to colorless transparent drops; and on charcoal fuses and volatilizes, tinging the flame green, and covering the charcoal with white tellurium dioxide.

Obs. Occurs in Hungary and Transylvania; also, Boulder Co., Colorado, at the Red Cloud Mine; in Magnolia District at the Keystone, Dun River, and other mines; in the Ballerat District at Smuggler Mine; in Central District at the John Jay Mine, where masses of 25 pounds weight are reported to have been found. *Lionite* is an impure variety from Mountain Lion Mine.

Tellurium is also a constituent of ores of gold, silver, mercury, bismuth, and lead, forming with the metals tellurides (pp. 102, 116, 117, 118, 129, 147); petzite and sylvanite (p. 118) are the most abundant, and large quantities—from Boulder Co., Colorado, chiefly—are smelted for gold and silver at Denver. Tellurium is not used in the arts.

Tellurite (*Tellurous acid*), TeO_2. The Keystone, Smuggler, and John Jay Mines; especially the last, where it is in minute white or yellowish crystals having one eminent cleavage.

Molybdenite.—Molybdenum Sulphide.

In hexagonal plates, or masses, thin foliated like graphite, and resembling that mineral. H. = 1–1.5. G. =

4.45–4.8. Color pure lead-gray; streak the same, slightly inclined to green. Thin laminæ very flexible; not elastic. Leaves a trace on paper, like graphite, but its color is slightly different, being bluish-gray.

Composition, MoS_2 = Sulphur 41.0, molybdenum 59.0 = 100. B.B. infusible; but when heated on charcoal, sulphur fumes are given off, which are deposited on the coal. Dissolves in nitric acid, excepting a gray residue.

Diff. Resembles graphite, but differs in its paler color and streak, and also in giving fumes of sulphur when heated, as well as by its solubility in nitric acid.

Obs. Occurs in granite, gneiss, mica schist, and allied rocks; also in granular limestone. Found in Sweden; at Arendal in Norway; in Saxony; Bohemia; Caldbeck Fell in Cumberland; and in the Cornish mines.

In the U. S. occurs at Blue Hill Bay, Camdage Farm, Brunswick, and Bowdoinham, Me.; at Westmoreland, Landaff, and Franconia, N. H.; at Shutesbury and Brimfield, Mass.; at Haddam and Saybrook, Ct.; near Warwick, N. Y.; near Franklin Furnace, N. J.

Molybdenum does not occur native. Yellow oxide is an occasional result of its alteration. Occurs combined with lead as a molybdate (page 151), which is the only native salt containing it. Named from the Greek *molubdaina*, meaning mass of lead, in allusion to the resemblance of molybdenite to graphite.

Tungstite (*Tungstic ochre*). A yellow powder or incrustation occurring with wolfram, and a result of its decomposition. Occasionally observed at Lane's Mine, Monroe, Ct. *Meymacite;* hydrous WO_3.

Besides this oxide there are the native compounds, iron tungstate or *wolfram* (p. 200), manganese tungstate (p. 200), lead tungstate (p. 66), and calcium tungstate (p. 232). Tungsten also occurs sparingly in some ores of niobium, as in certain varieties of the minerals pyrochlore, columbite, and yttro-columbite.

2. BORON GROUP.

In Boron, as in the Sulphur group, the most prominent oxide is a trioxide.

Sassolite.—Boracic Acid. Sassolin.

Occurs in small scales, white or yellowish. Feel smooth and unctuous. Taste acidulous and a little saline and bitter. G. = 1.48. *Composition*, $H_6O_6Bo_2$ = Boron trioxide 56.4, water 43.6. It is strictly *hydrogen borate.*

Fuses easily in the flame of a candle, tinging the flame at first green.

Found at the crater of Vulcano, and also at Sasso in Italy, whence it was called *Sassolin*. The hot vapors of the lagoons of Tuscany afford it in large quantities. The vapors are made to pass through water, which condenses them; and the water is then evaporated by the steam of the springs, and boracic acid obtained in large crystalline flakes. It still requires purification, as the best thus procured contains but 50 per cent of the pure acid. Occurs also in the waters of Lick Springs, Tehama Co., and Borax Lake, Lake Co., California, where it was first observed, through their evaporation, by Dr. J. A. Veatch, in 1856. It has since been obtained from the waters of Mono, Owens, and other lakes. It exists sparingly in the waters of the ocean. But in all these waters, it is probably in combination.

Boron occurs usually in the condition of magnesium, calcium, and sodium borates (pp. 225, 231, 246); and rarely as an iron borate (p. 182), or ammonium borate (p. 231). It also occurs in the silicates, tourmaline, danburite, axinite, and datolite, in which it is easily detected by the blowpipe reaction (p. 99). The borax of commerce (hydrous sodium borate) is derived mostly from native borax (p. 99), but also from the sodium-calcium borate (ulexite) and to some extent from sassolin.

3. THE ARSENIC GROUP.

The elements of the Arsenic group occurring among minerals are arsenic, antimony, bismuth, phosphorus, nitrogen, vanadium, tantalum, niobium. Of these, arsenic, antimony, and bismuth occur native, and as sulphides; also, in combination with other metals, constituting arsenides, antimonides, bismutides; and, along with sulphur also, making sulpharsenites, sulphantimonites, sulphbismutites. In addition, they all, excepting bismuth, enter into the constitution of a series of native ternary oxygen compounds, called, severally, arsenates, antimonates, phosphates, nitrates, vanadates, tantalates, niobates.

The chief oxide has the general formula R_2O_5.

Native Arsenic.

Rhombohedral. $R \wedge R = 85° 41'$. Cleavage basal, imperfect. Also massive, columnar, or granular.

Color and streak tin-white, but usually dark grayish from tarnish. Brittle. H. = 3·5. G. = 5·65–5·95.

B.B. volatilizes readily before fusing, with the odor of garlic; burns with a pale bluish flame when heated just below redness.

Obs. Occurs with silver and lead ores. Found in considerable quantities at the silver mines of Freiberg and Schneeberg; in Bohemia; the Hartz; at Kapnik in Upper Hungary; in Siberia in large masses, and elsewhere.

In the U. States observed sparingly at Haverhill and Jackson, N. H.; at Greenwood, Me.

Orpiment.—Yellow Arsenic Sulphide.

Orthorhombic. Cleavage highly perfect in one direction. In foliated masses, and sometimes in prismatic crystals. Color and streak fine yellow. Lustre brilliant pearly, or metallic pearly, on the face of cleavage. Subtransparent to translucent; sectile. H. = 1·5–2. G. = 3·4–3·5.

Composition. As_2S_3 = Sulphur 39·0, arsenic 61·0. Wholly evaporates before the blowpipe with an alliaceous odor, and on charcoal burns with a blue flame.

From Hungary, Koordistan in Turkey in Asia, China, and South America. Occurs at Edenville, N. Y., as a yellow powder, resulting from the decomposition of arsenical iron; Coyote Dist., Iron Co., Utah.

Realgar. The arsenic sulphide AsS. Color fine clear red, aurora-red to orange, transparent or translucent; H. = 1·5–2; G. = 3·35–3·65; *Composition,* AsS = Sulphur 29·9, arsenic 70·1 = 100. B.B. like the preceding. Hungary, Bohemia, Saxony, the Hartz, Switzerland, and Koordistan in Asiatic Turkey. Has been observed in the lavas of Vesuvius.

Realgar is one of the ingredients of *white Indian fire,* often used as a signal light. Orpiment is a coloring ingredient in the pigment called *king's yellow,* in which it is mixed with arsenous acid.

Arsenolite.—White Arsenic. Arsenous Acid.

Isometric. In minute capillary crystals, and botryoidal or stalactitic. Color white. Soluble; taste astringent, sweetish. H. = 1·5. G. = 3·7.

Composition. As_2O_3 = Arsenic 75·8, oxygen 24·2 = 100.

The common *arsenic* of the shops. Found sparingly native, accompanying ores of silver, lead, and arsenic, in the Hartz, Bohemia, and elsewhere. A well-known poison.

Claudetite is the same compound in orthorhombic forms; from Portugal.

General Remarks.—Arsenic is obtained for commerce chiefly from arsenopyrite (or mispickel), an iron sulph-arsenide, and from the nickel and cobalt arsenides, by first roasting off the sulphur, and then condensing the arsenic, in the state of As_2O_3 ("arsenous acid") in large chambers. Arsenopyrite is used for making the oxide at the Deloro mine in Ontario, Canada, where 200 tons were produced in 1884. To obtain the material pure it is usually sublimed again. In Devon and Cornwall the arsenical ores occur with the tin ore, and a large amount of white arsenic is made. The metal arsenic forms a small part of some alloys; the most important is that with lead for shot-making. 3,693,325 pounds of white arsenic were imported into the U. States in 1884, and 5,207,553 pounds in 1883.

Native Antimony.

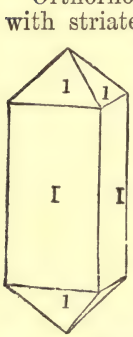
Rhombohedral; $R \wedge R = 87° 35'$. Usually massive, with a very distinct lamellar structure; sometimes granular. Color and streak tin-white. Brittle. H. = 3–3·5. G. = 6·6–6·75.

Composition. Pure antimony, often with a little silver, iron, or arsenic. B.B. on charcoal fuses easily and passes off in white fumes.

Obs. Occurs in veins of silver and other ores in Dauphiny; Bohemia; Sweden; the Hartz; Mexico; New Brunswick.

Stibnite.—Gray Antimony. Antimony Sulphide.

Orthorhombic; $I \wedge I = 90° 26'$. In right rhombic prisms, with striated lateral faces. Cleavage in the direction of the shorter diagonal, highly perfect. Commonly divergent columnar or fibrous. Sometimes massive granular.



Color and streak lead-gray; liable to tarnish. Lustre shining. Brittle; but thin laminæ a little flexible. Somewhat sectile. H. = 2. G. = 4·5–4·62.

Composition. Sb_2S_3 = Sulphur 28·2, antimony 71·8. Fuses readily in the flame of a candle. B.B. on charcoal it is absorbed, giving off white fumes and a sulphur odor.

Diff. Distinguished by its extreme fusibility and its vaporizing before the blowpipe.

Obs. In veins with ores of silver, lead, zinc, or iron, and often associated with barite, spathic iron, or quartz. Occurs at Felsöbanya and Schemnitz in Hungary; Wolfsberg in the Hartz; Bräunsdorf near Freiberg; in Auvergne; Cornwall; Spain; Portugal; Tuscany, Italy; Borneo; Shi-

koku, S. Japan, in magnificent crystals; N. S. Wales and Victoria, Australia.

In the U. States, sparingly at Carmel, Me., Lyme, N. H., and at "Soldier's Delight," Md.; abundant in San Emidio Cañon, Kern Co., Cal.; also in San Bernardino, Inyo, Mono, Lake, Tulare, and Monterey Cos., Cal.; in Relief district, Humboldt Co., Nev.; in the mines of Aurora, Esmeralda Co., Nev.; also 12 miles south of Battle Mountain, Nev.; in Utah, in Iron Co., on Coyote creek, abundant. Also worked in N. Brunswick, 20 miles west of Fredericton; in Rawdon township, Hants Co., N. Scotia.

Affords the most of the antimony of commerce. By simple fusion, the crude antimony of the shops is obtained, from which pure antimony and its pharmaceutical preparations are made. Antimony constitutes 17.20 per cent. of type-metal, 10 to 16 per cent. of Britannia metal, 8.3 per cent. of Babbitt metal, and about 7 of pewter.

Allemontite. Arsenical antimony, $Sb_2 As_3$. Allemont; Bohemia; the Hartz.

Valentinite. White antimony in white, grayish, or reddish rectangular crystals, with perfect cleavage, affording a rhombic prism of 136° 58′. Also in tabular masses, and columnar and granular. H.= 2·5–3. G.= 5·57. Lustre adamantine to pearly. *Composition*, $Sb_2 O_3$ = Oxygen 16·44, antimony 83·56 = 100. Bohemia; Hungary; Saxony; Dauphiny; Sonora, Mexico.

Senarmonite. Same as Valentinite, but isometric.

Kermesite or *Red antimony.* An antimony oxide and sulphide, in red tufts of capillary crystals; lustre adamantine. Hungary, Dauphiny, Saxony, the Hartz.

Cervantite. Antimony oxide, $Sb_2 O_4$, resulting from the decomposition of stibnite.

Livingstonite. Like stibnite, but contains 14 per cent. of mercury and has a *red streak.* Huitzuco and Guadalcazar, Mexico.

Native Bismuth.

Rhombohedral; $R \wedge R = 87° 40'$. Cleavage rhombohedral, perfect. Generally massive, with distinct cleavage; sometimes granular.

Color and streak silver white, with a slight tinge of red. Subject to tarnish. Brittle when cold, but somewhat malleable when heated. H. = 2–2·5. G. = 9·7–9·8. Fuses at a temperature of 476° F.

Composition. Pure bismuth, with sometimes a trace of arsenic, sulphur, or tellurium. B.B. on charcoal vaporizes, and leaves a yellow coating on the coal, paler on cooling.

Obs. Abundant with ores of silver and cobalt in Saxony

and Bohemia; also in Cornwall and Cumberland, England; in Norway, Sweden, Chili, and Bolivia; at the Balhannah mine, in S. Australia, with copper ore and gold. At Schneeberg, it forms arborescent delineations in brown jasper.

In the U. States, found at Lane's and Booth's mine, Monroe, Ct., with tungsten, galenite, and pyrite; at Brewer's mine, in Chesterfield district, S. C.; in Colorado; 12 miles west of Beaver City, Utah.

Bismuthinite. A bismuth sulphide, Bi_2S_3, in acicular crystals of a lead-gray color; also massive. Five miles N. of Golden, Col.; in Beaver Co., Utah; and elsewhere.

Guanajuatite. A bismuth selenide, called also *frenzelite*. *Silaonite*, from the same locality, is a mixture. Guanajuato, Mexico.

Tetradymite.—Bismuth Telluride.

Hexagonal; $R \wedge R = 81° 2'$. Crystals often tabular, with a very perfect basal cleavage. Also massive, and foliated or granular. Laminæ flexible. Lustre splendent metallic. Color pale steel-gray, a little sectile. H.=1·5—2. G.=7·2—7·9. Soils paper.

Composition. Consists of bismuth and tellurium, with sometimes sulphur and selenium. Affords for the most part the formula $Bi_2(Te, S)_3$. A variety from Dahlonega, Ga., gave Tellurium 48·1, bismuth 51·9=Bi_2Te_3; G.=7·642. *Joseite* is a bismuth telluride from Brazil, in which half the bismuth is replaced by sulphur; *Wehrlite* is another containing sulphur, from Deutsch Pilsen, Hungary, having G.=8·44.

Obs. Found with gold in Virginia, N. Carolina, and Ga.; Highland, Montana; Red Cloud Mine, Col.; Montgomery Mine, Arizona.

Bismite (Bismuth ochre). An impure oxide; grayish to greenish and yellowish white; massive or earthy. Found with native bismuth. *Bolivite* is a related mineral.

Daubréite. A bismuth oxychloride. Bolivia.

Bismutite. Bismuth carbonate; pale yellow to green, G.=7—7·5. Found with other bismuth ores. *Waltherite* and *Bismutosphærite* belong here. *Montanite* is bismuth tellurate; Montana; N. Car.

Pucherite. Bismuth vanadate; orthorhombic; reddish brown. Schneeberg, Saxony. *Atelestite*, *Rhagite*, bismuth arsenate.

Taznite. Supposed to be a bismuth arsenio-antimonate. Peru.

For the *sulpho-bismuthides*, see pp. 00, 00; and for a silicate, p. 0.

General Remarks.—The metal *bismuth* is obtained mostly from native bismuth, and the most valuable mines are in Saxony, Hungary, Baden, Cornwall, and Australia. Besides the above ores, there are

also others in which the metal is combined with silver, lead, and nickel (pp. 134, 183).

4. CARBON GROUP.

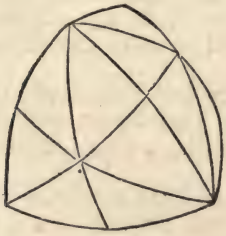
The Carbon group in chemistry comprises carbon and silicon, in which the formula for the most prominent oxide is RO_2. Only carbon occurs native.

Carbon occurs crystallized in the diamond and graphite; as oxides, in carbon oxide, and carbon dioxide (ordinarily called carbonic acid); combined with hydrogen, or hydrogen and oxygen, in bitumen, mineral oils, amber, and a number of native mineral resins, and mineral wax; and as the chief constituent of mineral coal, in which it is combined with more or less of hydrogen and oxygen and usually some nitrogen.

Diamond.

Isometric. In octahedrons, dodecahedrons and more complex forms; faces often curved. Cleavage octahedral; perfect.

1.



2.

Color white, or colorless; also yellowish, red, orange, green, blue, brown or black. Lustre adamantine. Transparent; translucent when dark-colored. H. = 10. G. = 3·48–3·55.

Composition. Pure carbon. Burns and is consumed at a high temperature, producing carbonic-acid gas. Exhibits vitreous electricity when rubbed. Some specimens exposed to the sun for a while give out light when carried to a dark place. Strongly refracts and disperses light.

Diff. Distinguished by the hardness; brilliant reflection of light and adamantine lustre; vitreous electricity when rubbed, which is not afforded by other gems unless they are

polished; and, to the practised ear, by means of the sound when rubbed together.

Obs. Coarse diamonds, unfit for jewelry, are called *bort*, and the kind in black pebbles, or masses, from Brazil, *carbonado*. The latter occur sometimes in pieces 1000 carats in weight; they have G. = 3 to 3·42. Another kind is much like anthracite, G. = 1·66, although as hard as diamond crystals; it is in globules or mammillary masses, often partly made up of concentric layers.

Diamonds occur in India, in the district between Golconda and Masulipatam, and near Parma, in Bundelcund, where some of the largest have been found; also on the Mahanuddy, in Ellore. In Borneo, they are obtained on the west side of the Ratoos Mountain, with gold and platina. The Brazilian mines were first discovered in 1728, in the district of Serra do Frio, to the north of Rio de Janeiro; the most celebrated are on the river Jequitinhonha, which is called the Diamond River, and the Rio Pardo; seventy to seventy-five thousand carats are exported annually from these regions. In the Urals of Russia they had not been detected till July, 1829, when Humboldt and Rose were on their journey to Siberia. The river Gunil, in the province of Constantine, in Africa, is reported to have afforded some diamonds.

In South Africa, where they were first discovered in 1867, they occur in the gravel of the Vaal River and in the Orange River country. In Australia, on the Macquarie, and elsewhere.

In the United States, the diamond has been met with in Rutherford, Lincoln, Mecklenburg, Franklin, and other counties, N. C.; Hall Co., Ga.; Manchester, opposite Richmond, Va., a crystal weighing 24¾ carats before cutting, and nearly half that after cutting; also in Cherokee Flat, and other places in Butte Co., Forest Hill in El Dorado Co. (one weighing nearly 1½ carats), Fiddletown in Amador Co., San Juan Co. in Colorado; in Nevada Co., Cal.; and with platinum on the coast of Southern Oregon; and one fine stone of ⅝ths carat, near San Francisco. It has been reported from Idaho, Arizona, Montana; also from the drift in Waukesha Co., Wis., one of 15 carats.

The original rock in Brazil appears to be either a laminated quartzyte (itacolumyte), or a ferruginous quartzose conglomerate. The itacolumyte occurs in the Urals, and

diamonds have been found in it; and it is also abundant in Georgia and North Carolina. According to Genth, the auriferous sands in N. Carolina, affording the diamond with zircons, monazite, etc., are the débris of gneiss and mica schist, and some graphite is always present. In India, the rock is a quartzose conglomerate. The origin of the diamond has been a subject of speculation, and it is the prevalent opinion that the carbon, like that of coal, much graphite, and mineral oil, is of vegetable or animal origin. Some crystals have been found with black uncrystallized particles or seams within, looking like coal; and this fact has been supposed to indicate such an origin.

Diamonds, with few exceptions, are obtained from alluvial washings. In Brazil, the sands and pebbles of the diamond rivers and brooks (the waters of which are drawn off in the dry season to allow of the work) are collected and washed under a shed, by a stream of water passing through a succession of boxes. A washer stands by each box, and inspectors are stationed at intervals.

Diamonds are valued according to their color, transparency, and size. The rose diamond is more valuable than the pure white, owing to the great beauty of its color and its rarity. The green diamond is much esteemed on account of its color. The blue is prized only for its rarity, as the color is seldom pure. The black diamond, which is uncommonly rare and without beauty, is highly prized by collectors. The brown, gray, and yellow varieties are of much less value than the pure white or limpid diamond.

The largest diamond on record (doubtful) is that mentioned by Tavernier as in the possession of the Great Mogul. It weighed originally 900 carats, or 2769·3 grains, was reduced by cutting to 861 grains, had the form and size of half of a hen's egg, and is said to have been found in 1550, in the mine of Colone. The diamond which formed the eye of a Braminican idol, and was purchased by the Empress Catherine II. of Russia from a French grenadier who had stolen it, weighs 194¾ carats, and is as large as a pigeon's egg. The Austrian crown has a diamond weighing 139½ carats. The Pitt or Regent diamond is of less size, it weighing but 136·25 carats, or 419¼ grains; but on account of its unblemished transparency and color it is considered the most splendid of Indian diamonds. It was sold to the Duke of Orleans by Mr. Pitt, an English gentleman, who

was governor of Bencoolen, in Sumatra, for £130,000. It is cut in the form of a brilliant, and is estimated at £125,000. The Rajah of Mattan has in his possession a diamond from Borneo, weighing 367 carats. The Koh-i-noor, on its arrival in England, weighed 186·016 carats.* It is said by Tavernier to have originally weighed 787½ carats. It has since been recut and reduced one third in weight.

In the Dresden Treasury there is an emerald-green diamond weighing 31¼ carats. The *Hope* diamond, weighing 44⅝ carats, has a beautiful sapphire-blue color.

The diamonds of Brazil are seldom large. Maure mentions one of 120 carats, but they rarely exceed 18 or 20. One weighing 254½ carats, called the "*Star of the South*," was found in 1854.

Of South African diamonds, the "Schreiner" weighed, in its rough state, 308 carats; and the "Stewart," which has a light straw color, 288·35 carats; and one of 475 carats was reported in 1885 as about to be cut at Amsterdam. The diamonds of South Africa are mostly "off color"; about 10 per cent. are of first quality; 15, 2d; 20, 3d; and 55 per cent. are *bort* (W. J. Morton). The "Star of South Africa," of pure water, weighed 83·5 carats. Some crystals crack to pieces after being exposed to the air awhile.

The diamond is cut by taking advantage of its cleavage, and also by abrasion with its own powder. The flaws are sometimes removed by cleaving it. Afterwards the crystal is fixed to the end of a stick of soft solder when the solder is in a half-melted state, leaving the part projecting which is to be cut. A circular plate of soft iron is then charged with the powder of the diamond, and this, by its revolution, grinds and polishes the stone. By changing the position, other facets are added in succession till the required form is obtained. Diamonds were first cut in Europe, in 1456, by Louis Berghem, a citizen of Bruges; but in China and India the art of cutting appears to have been known at a very early period.

By the above process, diamonds are cut into *brilliant, rose,* and *table* diamonds. The brilliant has a *crown* or upper part, consisting of a large central eight-sided facet, and a

* A carat is a conventional weight. In England it equals 3·174 grains troy. Schrauf makes it vary in Europe from 197·20 mgr. to 206·13, and in London 205·409. The term *carat* is derived from the name of a bean in Africa, which, in a dried state, has long been used in that country for weighing gold. These beans were early carried to India, and were employed there for weighing diamonds.

series of facets around it; and a *collet*, or lower part, of pyramidal shape, consisting of a series of facets, with a smaller series near the base of the crown. The depth of a brilliant is nearly equal to its breadth, and it therefore requires a thick stone. Thinner stones, in proportion to the breadth, are cut into rose and table diamonds. The surface of the *rose* diamond consists of a central eight-sided facet of small size, eight triangles, one corresponding to each side of the table, eight trapeziums next, and then a series of sixteen triangles. The collet side consists of a minute central octagon, surrounded by eight trapeziums, corresponding to the angles of the octagon, each of which trapeziums is subdivided by a salient angle into one irregular pentagon and two triangles. The *table* is the least beautiful mode of cutting, and is used for such fragments as are quite thin in proportion to the breadth. It has a square central facet, surrounded by two or more series of four-sided facets, corresponding to the sides of the square.

Diamonds have also been cut with figures upon them. As early as 1500, Charadossa cut the figure of one of the Fathers of the church on a diamond, for Pope Julius II.

Diamonds are employed for cutting glass; and for this purpose only the natural edges of crystals can be used, and those with curved faces are much the best. Diamond dust is used to charge metal plates of various kinds for jewellers, lapidaries, and others. Drills are made of small splinters of bort, and used for drilling other gems, and also for piercing holes in artificial teeth and vitreous substances generally; and others of iron set with a few diamonds, for drilling rocks.

Graphite.—Plumbago.

Hexagonal. Sometimes in six-sided prisms or tables with a transversely foliated structure. Usually foliated, and massive; also granular and compact.

Lustre metallic, and color iron-black to dark steel-gray. Thin laminæ flexible. H. = 1–2. G. = 2·25–2·27. Soils paper, and feels greasy.

Composition. Commonly 95 to 99 per cent. of carbon. B.B. infusible, both alone and with reagents; not acted upon by acids.

Diff. Resembles molybdenite, but differs in being unaffected by the blowpipe and acids. The same characters

distinguish the granular varieties from any metallic ores they resemble.

Obs. Graphite (called also *black lead*) is found in crystalline rocks, in veins, and as a constituent of mica schist or gneiss; also in crystalline limestone; in argillyte, and occasionally in sandstone. In Rhode Island and at Worcester, Mass., it occurs in beds of the coal formation. Its principal English locality at Borrowdale, in Cumberland, is now nearly exhausted.

In the U. States it is worked at Roger's Rock, near Ticonderoga; less abundant in gneiss at Sturbridge, Mass.; North Brookfield, Brimfield, and Hinsdale, Mass.; Cornwall and Ashford, Ct.; Brandon, Vt.; Rossie, in St. Lawrence Co.; near Amity, Orange Co., N. Y.; Greenville, N. C.; near Attleboro, in Bucks County, Pa.; Wake, N. C.; on Tyger River, and at Spartanburg, near the Cowpens Furnace, and Greenville, S. C.; Albany Co., Wyoming; Pitkin, Gunnison Co., Col.; Black Hills, Dak.; Sonora Mine, Tuolumne Co., Cal.; N. Mexico; also of excellent quality in Canada, in Buckingham, Fitzroy, and Grenville, but not worked in 1884.

Ceylon, Bavaria, and Siberia afford most of the foreign graphite. About 17,348,000 pounds were imported into the U. States in 1883. In the same year the yield of the U. States was only 575,000 pounds, and all was from the Ticonderoga mine; in 1884 this mine was not worked.

For the manufacture of the best pencils the granular graphite was thought necessary, and hence the former great value of the Borrowdale mine, where the texture was peculiarly fine and firm. But now the graphite is ground up, and then compressed under heavy pressure, and thus the fine texture and firmness required may be obtained with any pure graphite, though some cement is generally used; fine clay is added to make the harder pencils.

Graphite is extensively employed for diminishing the friction of machinery; also for the manufacture of crucibles and furnaces; in electrotyping; as a polish for iron stoves and railings. For crucibles it is mixed with half its weight of clay. Price, 1–10 dollars per cwt., according to quality.

Carbonic Acid.

Carbonic acid—carbon dioxide of chemistry—is the gas that gives briskness to the Saratoga and many other mineral

waters, and to artificial "soda water." Its taste is slightly pungent. It extinguishes combustion and destroys life.

Composition. CO_2 = Oxygen 72·35, carbon 27·65 = 100.

This gas is contained in the atmosphere, constituting about 3 parts, by volume, in 10,000 parts; and it is present in minute quantities in the waters of the ocean and land. It is given out by animals in respiration, and is one of the results of animal and vegetable decomposition; and from this source the waters derive much of their carbonic acid. This gas is the *choke-damp* of mines, where it is often the occasion of the destruction of life. It is often present also in wells.

Carbon dioxide (or carbonic acid) is given out by limestone (or calcium carbonate) when it is heated; and quicklime is limestone from which CO_2 has been expelled by heat, a process carried on usually in a *limekiln*. It is expelled also by sulphuric acid, with the formation of gypsum (a hydrous calcium sulphate), or anhydrite (an anhydrous calcium sulphate), and this is one source of gypsum beds in rocks of different ages. These processes are often carried on in volcanoes, and hence carbonic-acid gas is common in some volcanic regions. The *Grotto del Cane* (Dog Cave) at the Solfatara near Naples is a small cavern filled to the level of the entrance with this gas. It is a common amusement for the traveller to witness its effect upon a dog kept for that purpose. He is held in the gas awhile and is then thrown out apparently lifeless; in a few minutes he recovers himself, picks up his reward, a bit of meat, and runs off as lively as ever. If continued in the carbonic-acid gas a short time longer, life would have been extinct.

Carbonic acid, under high pressure, becomes a liquid, and, with pressure and cold, a white snowlike solid. In the liquid state it is often found in microscopic globules in the interior of crystallized quartz, topaz, and some other minerals; and when this is true, calcite (calcium carbonate) is often present in the same or an adjoining rock.

Besides the calcium carbonate in nature, there are also carbonates of ammonium, sodium, barium, strontium, magnesium, iron, manganese, zinc, copper, lead, nickel, cobalt, bismuth, uranium, cerium, and lanthanum.

II. MINERALS CONSISTING OF THE BASIC ELEMENTS WITH OR WITHOUT ACIDIC—THE SILICATES EXCLUDED.

I. GOLD.

Gold occurs mostly native, being either pure, or alloyed with silver and other metals. It is occasionally found mineralized by tellurium, making part of the valuable minerals Sylvanite, Nagyagite, and Petzite.

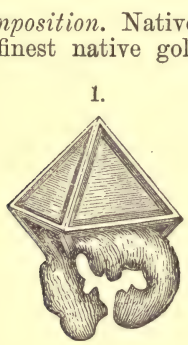
Native Gold.

Isometric. In octahedrons, dodecahedrons; without cleavage. Also in arborescent forms, consisting of strings of crystals, filiform, reticulated; also in grains, thin laminæ or scales, and in masses.

Color various shades of gold-yellow, paler when alloyed with silver, and occasionally nearly silver-white. Eminently ductile and malleable. H. = 2·5–3. G. when pure (native) 19–19·30, varying to 15 and 12 according to the metals alloyed with the gold. Fuses at 2016° F. (1102° C.).

Composition. Native gold is usually alloyed with silver. The finest native gold from Russia yielded gold 98·96,

1.



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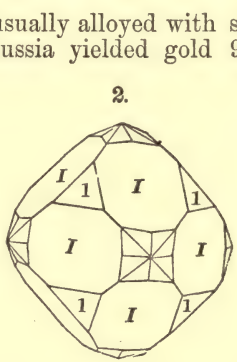


silver 0·16, copper 0·35, iron 0·05; G. = 19·099. A gold from Marmato afforded only 73·45 per cent. of gold, with 26·48 per cent. of silver; G. = 12·666. This last is in the proportion of 3 of gold to 2 of silver. The following proportions also have been observed: 3½ to 2; 5 to 2; 3 to 1;

4 to 1, and this the most common; 6 to 1 is also of frequent occurrence. Average of California native gold is 88 per cent. gold, and the range mostly between 87 and 89; the range of the Canadian, mostly between 85 and 90; of Australian, between 90 and 96 per cent., and the average 93½. The Chilian gold afforded Domeyko 84 to 96 per cent. of gold, and 15 to 3 per cent. of silver. The more argentiferous gold has been called *Electrum;* the atomic proportion of 1 : 1 between the gold and silver corresponds to 35·5 per cent. of silver, and that of 2 : 1, to 21·6 per cent.

Copper is occasionally found in alloy with gold, and sometimes also iron, bismuth, palladium, and rhodium. A *rhodium-gold* from Mexico gave the specific gravity 15·5–16·8, and contained 34 to 43 per cent. of rhodium. A bismuth gold has been called *Maldonite.*

Diff. Iron and copper pyrites are often mistaken for gold by those inexperienced in ores; but these are brittle minerals, while gold may be cut in slices, and flattens under a hammer. Pyrite is too hard to yield at all to a knife, and copper pyrites (chalcopyrite) affords a dull greenish powder. Moreover pyrite gives off sulphur when strongly heated, while gold melts without odor.

Obs. Mostly confined to veins of quartz, intersecting or interlaminated with subcrystalline slaty or schistose rocks, especially hydromica and chloritic schists; occurs sparingly in similar or other veins in granite, gneiss, or mica schist; sometimes occurs in slate rocks adjoining the veins. Found in traces, according to J. J. Stevenson, in the trachytes of Colorado, and in Silurian and Carboniferous quartzites. Gold also exists in sea-water—nearly 1 grain to a ton of water.

The quartz is frequently cellular for a considerable distance from the surface owing to the alteration and removal of pyrite, galena, or other metallic ores that may be accompaniments of the gold, and the cavities are usually rusty with oxide of iron, and sometimes contain particles of sulphur left by the decomposing pyrite, and also strings or laminæ of gold derived from the decomposed minerals. The rock in this cavernous state is rather easily quarried out; but deep below, where the minerals are not removed by decomposition, mining is far more difficult. The auriferous quartz often contains no gold that the naked eye or even a pocket lens can detect. The pyrite of a gold region

is often so auriferous as to make a very valuable gold ore, and this is true also of galenite.

While quartz veins are to a large extent the original repositories of native gold, a large part of the gold of auriferous regions comes from the sand and gravel beds, in which it occurs in flattened grains, and sometimes in lumps or nuggets. By different methods—erosion by running waters, movements of glaciers, natural decomposition, and other disintegrating action—the gold-bearing rocks have been extensively reduced to earth and stones, and this loose material has been distributed along the river-courses, making vast alluvial or diluvial gravelly formations. From these gravels the gold is obtained by simple washing, thus taking advantage of the high specific gravity of gold. Streams are carried in aqueducts and thrown in great jets against the gravel bluffs to reduce the material to loose earth and prepare it for further washing by the same water in sluices arranged for the purpose.

The minerals most common in gold regions are platinum, iridosmine, magnetite, pyrite, galenite, ilmenite, chalcopyrite, blende, arsenopyrite, tetradymite, zircon, rutile, barite; also in some cases wolfram, scheelite, brookite, monazite, and diamond. Platinum and iridosmine accompany the gold of the Urals, Brazil, and California; and diamonds are found in the gold region of Brazil, and occasionally in the Urals, United States, and Australia. Auriferous pyrite is worked for its gold in Colorado, and arsenopyrite at Deloro in Canada.

Gold is widely distributed over the globe. In AMERICA, it occurs in Brazil (where formerly a greater part of that used was obtained) along the chain of mountains which runs nearly parallel with the coast, especially near Villa Rica, and in the province of Minas Geraes; in New Granada, at Antioquia, Choco, and Giron; in Chili; sparingly in Peru and Mexico; in Arizona; in the Coast Range, and, much more abundantly, in the Sierra Nevada, Cal.; in Oregon, British Columbia, and Alaska; in New Mexico, Colorado, and Wyoming, the Black Hills in Dakota, and other parts of the Rocky Mountain region; in the Appalachians from Virginia to Georgia, a region that formerly produced annually nearly a million of dollars; sparingly in Vermont, New Hampshire, and other New England States; in Nova Scotia along its southern shore, chiefly to the eastward of Halifax;

in Beauce County, Canada; also, north of Lake Superior; and in the gravel of Illinois and Indiana.

In EUROPE, it occurs sparingly in Cornwall and Devon, England; North Wales, Scotland, and Ireland, formerly in the County of Wicklow, where a nugget of 22 ounces was found; and in France, very sparingly in the Department of Isère; in the sands of the Rhine, the Reuss, and the Aar; in Tyrol and Salzburg; on the southern slope of the Pennine Alps, from the Simplon and Monte Rosa to the Valley of Aosta, Northern Piedmont, where nearly 6000 ounces were obtained in 1867; more abundantly in Hungary, at Königsberg, Schemnitz, and Felsobanya, and in Transylvania, at Kapnik, Vöröspatak, and Offenbanya; in Spain, formerly worked in Asturias; in Sweden, at Edelfors.

In the Urals are valuable mines at Beresof, and other places on the eastern or Asiatic flank of this range, and the comparatively level portions of Siberia; also in the Altai Mountains. Also in the Cailas Mountains in Little Thibet; sparingly in the rivers of Syria and other parts of Asia Minor; in Ceylon, China, Japan, Formosa, Java, Sumatra, Western Borneo, the Philippines, and New Guinea.

In AFRICA, at Kordofan, between Darfour and Abyssinia; also south of Sahara, in the western part of Africa, from the Senegal to Cape Palmas; also along the coast opposite Madagascar, between the 22d and 35th degrees south latitude, in the Transvaal Republic. Other regions are Tasmania, New Zealand, and New Caledonia.

General Remarks.—The most productive gold regions at the present time are those of Australia and California.

In Australia the richest mines are those of Victoria and New South Wales. Victoria yielded, in 1856, 3,000,000 ounces, and in 1875, 1,195,250; New South Wales, in 1875, 227,000 ounces; and all Australia in 1884, $29,000,000. The Australian gold was first made known to the world in 1851. The localities discovered were on Summer Hill Creek and the Lewis Pond River (near lat. 33° N., long. 149°–150° E.), streams which run from the northern flank of the Coriobolas down to the river Macquarie, a river flowing westward and northward; it was soon afterward found on the Turon River, which rises in the Blue Mountains; and finally a region of country 1000 miles in length, north and south, was proved to be auriferous; the country is a region of metamorphic rocks, granite and slates, and in many parts abounds in quartz veins. Queensland and South Australia, and also Tasmania and New Zealand, afford gold.

Gold was first discovered in California in the spring of 1848, in placer deposits on the American Fork, a tributary to the Sacramento,

near the mouth of which Sutter's establishment was situated. Soon the gravels along Feather River, another affluent, 18 or 20 miles north, were proved to abound in gold about its upper portions; and it was not long after before each stream in succession, north and south, along the western slope of the Sierra Nevada was found to flow over auriferous sands. The gold region as now developed extends along that chain, through the whole length of the great north and south valley which holds the rivers and plains of the Sacramento and San Joaquin. It continues south nearly to the Tejon pass, in latitude 35°, and north beyond the Shasta Mountains to the Umpqua, and less productively into Oregon and Washington, and in British Columbia and Alaska. Gold also occurs in some places in the Coast range of mountains. Even the site of San Francisco has been found to contain traces. North of Shasta Mountain there are mines on the Klamath and the Umpqua, and on the sea-shore between Gold Bluff, in 41° 30′ south of the Klamath (30 miles south of Crescent City) to the Umpqua.

The yield of gold in the United States up to 1848, before the opening of the California mines, was $13,250,000; during the year 1848 to 1879 inclusive, $1,484,000,000; years 1880 to 1884 inclusive $163,000,000; making a total of $1,647,013,250.

In California, the yield of gold for 1848 was about $45,000; for 1849, over 6,000,000; for 1850, over 36,000,000; and for 1851 to 1857 inclusive, an average of $55,000,000; after which there was a gradual decline from the exhausting of the placer deposits; in 1863, it was $30,000,000; in 1870, $28,500,000; in 1872, $20,000,000; in 1884, $13,600,000.

In Colorado, gold mines occur in Gilpin County, among Archæan rocks, and much less productively in Clear Creek, Park, Boulder, Lake, Summit, Rio Grande, San Miguel, and La Plata counties. The yield in 1874 amounted to $2,102,487, of which $1,525,447 were from Gilpin County; in 1884, $4,250,000.

Nevada, where gold was first discovered in 1850, produced from the Comstock lode (see p. 123), in 1858, 1859, its first years, $257,000; in 1875, about $11,740,000, and the rest of Nevada, $2,256,000, making in all nearly $14,000,000; and in 1876, the Comstock lode yielded $18,000,000, and the rest of Nevada about $1,338,000; but all Nevada, in 1884, only $3,500,000.

For the several States and Territories in 1884, the yield of gold was as follows:

California	$13,600,000	Alaska	$200,000
Colorado	4,250,000	North Carolina	157,000
Nevada	3,500,000	Georgia	137,000
Dakota	3,300,000	Utah	120,000
Montana	2,170,000	Washington	85,000
Idaho	1,250,000	South Carolina	57,000
Arizona	930,000	Wyoming	6,000
Oregon	660,000	Virginia	2,000
New Mexico	300,000	Alabama, Tenn., etc	76,000

The yield of the United States in gold and silver from 1870 to 1884 was as follows:

	Gold.	Silver.	Total.
1870.....	$33,750,000	$17,320,000	$51,070,000
1871.....	34,398,000	19,286,000	53,684,000
1872	38,177,395	19,924,429	58,101,824
1873.....	39,206,558	27,483,302	66,689,860
1874.....	38,466,488	29.699,122	68,165,610
1875.....	39,968,194	31,635,239	71,603,433
1876.....	42,886,935	39,292,924	82,179,859
1877.....	44,880,223	45.846,109	90,726,332
1878.....	37,576,030	37,248,137	74,824,167
1879.....	31,420,262	37,032,857	68,453,119
1880.....	32,559.067	38,033,055	70,592,122
1881.....	30.653,959	42,987.613	73,641.572
1882.....	29,011.318	48,133,039	77,144,357
1883.....	30,000,000	46.200,000	76,200,000
1884.....	30,800,000	48,800,000	79,600,000

The yield of Nova Scotia in 1884 was 16,079 ounces, and in 1885 22,203 ounces. The Central and South American States yielded of gold in 1882, Mexico, 936,223; Venezuela, 2,595,077; Colombia, 3,856,000; Brazil, 741,694; Peru, 119,250; Chili, 163,000; Argentine Republic. 78,546; Bolivia, 72,375; making a total of a little more than 8,560,000 dollars. The yield of gold from all America from 1492 to the year 1800, was about $1,872,300,000.

From 1800 to 1847 inclusive, 48 years, the yield from America, Europe, and Africa is stated at $429,200,000; and from 1848 to 1876 inclusive, 29 years, $3,381,500,000. The largest annual amount was produced in the year 1856, in which the yield was $147,600,000; and next to this, in 1859, with $144,900,000; as shown in the annexed table, giving the amounts in millions of dollars:

1848..... 67·5	1858 .....144·6	1868.....109·7
1849..... 87·0	1859.....144·9	1869..... .106·2
1850..... 93·2	1860.....119·3	1870.....106·9
1851.....120·0	1861.....113·8	1871.....107·0
1852.....193·7	1862.....107·8	1872..... 99·6
1853.....155·0	1863.....107·0	1873..... 97·2
1854.....127·0	1864.....113·0	1874..... 90·8
1855.....135·0	1865.....130·7	1875..... 97·5
1856 .....147·6	1866.....122·2	1876..... 90·0
1857.....133·3	1867.....114·0	1884..... 41·2

The following table gives totals for the years stated:

	Russia.	United States.	Mexico and South America.	Australia.	Other Countries.	Total.
1850....	$16,950,000	$27,500,000	.....	.....	.....	.....
1855....	14,200,000	73,700,000	$5,000,000	$60,325,000	$2,500,000	$155,725,000
1860....	15,265,000	46,000,000	4,500,000	53,500,000	2,500,000	120,765,000
1865....	16,135,000	53,225,000	4,000,000	44,100,000	2,500,000	119,960,000
1870....	22,070,000	33,750,000	2,500,000	29,150,000	2,500,000	89,970,000
1875....	20,000,000	40,000,000	3,750,000	28,750,000	2,500,000	95,000,000
1884....	22,000,000	30,800,000	9,400,000	28,500,000	4,300,000	95,000,000

Masses of gold of considerable size have been found in North Carolina. The largest was discovered in Cabarrus County; it weighed 28 pounds avoirdupois ("steel-yard weight," equals 37 pounds troy), and was 8 or 9 inches long, by 4 or 5 broad, and about an inch thick. In Paraguay pieces from 1 to 50 pounds weight were taken from a mass of rock which fell from one of the highest mountains.

The largest masses of gold yet discovered have been found in auriferous gravel. The "Blanch Barkley Nugget," found in South Australia, weighed 146 pounds, and only six ounces of it were gangue; and one still larger, the "Welcome Nugget," from Victoria, weighed 2195 ounces, or nearly 183 pounds, and yielded £8376 10*s.* 6*d.* sterling of gold. Two others from Victoria weighed 1621 and 1105 ounces. In Russia, a mass was found in 1842, near Miask, weighing 96 pounds troy; another of 27 pounds and several of 16 pounds have been found in the Urals. The largest mass reported from California weighed 160 pounds. A remarkably beautiful mass, consisting of a congeries of crystals, weighing 201 ounces (value $4000), was found in 1865, seven miles from Georgetown, in El Dorado County.

The origin of gold veins, or rather of the gold in the veins, is little understood. The rocks, as has been stated, are metamorphic slates that have been crystallized by heat; and they are the hydromica, chloritic, and argillaceous, that have been but imperfectly crystallized, rather than the mica schist and gneiss, which are well crystallized; and the veins of quartz which contain the gold occupy fissures through the slates and openings among the layers, which must have been made when the metamorphic changes or crystallization took place. It was a period, for each gold region, of long-continued heat (occupying, probably, a prolonged age), and also of vast upliftings and disturbances of the beds; for the beds are tilted at various angles, and the veins show where were the fractures of the layers, or the separations and gapings of the tortured strata. The heat appears not to have been of the intensity required for the better crystallization of the more perfectly crystalline schists. The quartz veins could not have been filled from below, by injection; they must have been filled either laterally, or from above. In all such conditions of upturning and metamorphism, the moisture present would have become intensely heated, and hence have had great dissolving and decomposing power; it would have taken up silica with alkalies from the rocks (as happens in all Geyser regions), along with whatever other mineral substances were capable of solution or removal; and the vapor, thus laden, would have

filled all open spaces, there to make depositions of the silica and other ingredients it contained. These mineral ingredients would have been derived either from the rock adjoining the veins or opened spaces, or from depths below through ascending vapors. By one or both of these means the quartz must have received its gold, pyrite, and ores of lead, copper, and other materials—all having been carried into the open cavities at the same time with the silica or quartz. The pyrite of the vein, by being auriferous, shows that it was crystallized under the same circumstances that attended the depositing of the gold in strings, crystals, and grains; and the same is often true of the galena.

Gold coin of the United States contains 90 parts of gold to 10 of an alloy of copper and silver, and an eagle weighs 258 grains. An ounce of pure gold is worth about $20.67.

Calaverite. A bronze-yellow gold telluride; G. = 9·043; Au Te_2 = Tellurium 55·5, gold 44·5 = 100, with a little silver. Occurs massive at the Stanislaus Mine, California, and the Red Cloud Mine, Colorado, and also the Keystone and Mountain Lion mines, in the Magnolia District.

Krennerite. Another gold telluride, silver-white to brass-yellow, from Nagyag in Transylvania.

Sylvanite, called also *Graphic tellurium* (see p. 132).

Nagyagite. Telluride of lead containing gold (see p. 149).

Petzite. Telluride of silver and gold, allied to Hessite (p. 132).

II. SILVER.

Silver occurs native, and alloyed with gold; also combined with sulphur, selenium, tellurium, arsenic, antimony, bismuth, chlorine, bromine, or iodine; but never as an oxide, carbonate, sulphate, or phosphate.

Native Silver.

Isometric. In octahedrons and other forms. No cleavage apparent. Often in filiform and arborescent shapes, the threads having a crystalline character; also in laminæ, and massive.

Color and streak silver-white and shining. Often black externally from tarnish. Sectile. Malleable. H. = 2·5–3. G. = 10·1–11·1 (for pure silver, 10·92).

Composition. Usually an alloy of silver and copper, the latter often amounting to 10 per cent. Also alloyed with gold, as mentioned under that metal. A *bismuth silver* from Copiapo, S. A., contained 16 per cent. of bismuth.

B.B. fuses easily to a silver-white globule. Dissolves in nitric acid, from which it is precipitated as white chloride

on adding hydrochloric acid. A clean plate of copper immersed in the nitric solution becomes coated with silver. Sulphur gases blacken or tarnish silver, producing a sulphide.

Diff. Distinguished by being malleable; from bismuth and other white native metals by affording no fumes before the blowpipe; by affording a precipitate with hydrochloric acid (the chloride of silver, which becomes black on exposure.

Obs. Occurs in masses and string-like arborescences, penetrating the gangue, or its minerals, in various silver mines. It is also found mixed with native copper. Sea-water contains 1 part in 100 million; and it has been calculated that the whole amount in the ocean is not less than 2,000,000 tons.

The mines of Norway, at Kongsberg, formerly afforded magnificent specimens of native silver, but they are now mostly under water. One mass from this locality, at Copenhagen, weighs 500 pounds; and two other masses have been found of 238 and 436 pounds. Other European localities are in Saxony, Bohemia, the Hartz, Hungary, Dauphiny. Peru and Mexico also afford native silver. A Mexican specimen from Batopilas, weighed when obtained 400 pounds; and one from Southern Peru (mines of Huantajaya) weighed over 8 cwt. Arizona is reported to have produced one mass weighing 2700 pounds. In the United States, in the Lake Superior region, the silver generally penetrates the copper in masses and strings, and is very nearly pure, notwithstanding the copper about it. Large masses occur at the Idaho Silver Mine, called the Poor Man's Lode; and in strings it is occasionally found in the mines of Nevada, California, and Colorado. Native silver has also been observed at the Bridgewater copper mines, N. J.; and in handsome specimens at King's Mine, Davidson Co., N. C.; Newburyport, Mass.

Native Amalgam. Silver-white; consists of silver and mercury; the compounds Ag Hg = Silver 35·1, mercury 64·9, and Ag_2Hg_3 = Silver 26·5, mercury 73·5, are included.

Arquerite. A kind from Chili; contains 86·6 per cent. of silver ($Ag_{12}Hg$); from Arqueros; Vitalle Creek, British Columbia. Another, $Ag_{18}Hg$, is *Kongsbergite*, from Kongsberg, Sweden; Arqueros, Chili. Another has been called *Bordosite*.

SULPHIDES, SELENIDES, TELLURIDES, ANTIMONIDES.

Argentite.—Silver Glance. Sulphuret of Silver.

Isometric. In dodecahedrons more or less modified. Cleavage sometimes apparent parallel to the faces of the dodecahedron. Also reticulated and massive.

Lustre metallic. Color and streak blackish lead-gray; streak shining. Very sectile. H. = 2–2·5. G. = 7·19–7·4.

Composition. When pure, Ag_2S = Sulphur 12·9, silver 87·1. B.B. on charcoal in O.F. intumesces, gives off the odor of sulphur, and finally affords a globule of silver.

Diff. Resembles some ores of copper and lead, and other ores of silver, but is distinguished by being easily cut, like lead, with a knife; and also by affording a globule of silver on charcoal by heat alone. Its specific gravity is much higher than that of any copper ores.

Obs. This important ore of silver occurs in Europe principally at Annaberg, Joachimsthal, and other mines of the Erzgebirge; at Schemnitz and Kremnitz, in Hungary, and at Freiberg in Saxony. It is a common ore at the Mexican silver mines, and also in the mines in South America. It occurs in Arizona, with chalcocite, at the Heintzelman Mine; in Nevada; in Colorado, Clear Creek Co., near Georgetown. A mass of "sulphuret of silver" is stated by Troost to have been found in Sparta, Tennessee.

Acanthite. An orthorhombic silver sulphide, Ag_2S, from Joachimstahl. *Daleminzite.* Another, from near Freiberg.

Stromeyerite. Steel-gray silver-copper sulphide, $Ag_2S + Cu_2S$ = Sulphur 15·7, silver 53·1, copper 31·2 = 100; H = 2·5–3; G. = 6·26; B.B. fuses and gives in the open tube an odor of sulphur, but yields a silver globule only by cupellation with lead. Peru, Silesia, Chili, Siberia, and Arizona.

Sternbergite. Silver-iron sulphide, containing 30 to 35 per cent. of silver; highly foliated, resembling graphite, and like it leaving a tracing on paper; the thin laminæ flexible; color pinchbeck brown; streak black; G. = 4·215. Joachimsthal and Johanngeorgenstadt; Arizona. *Argyropyrite* (G. = 4·206) from Freiberg, and *Frieseite* from Joachimsthal, are varieties of *sternbergite*. *Argentopyrite* contains 26·5 of silver, and is a related species, from Andreasberg.

Naumannite. Silver-lead selenide, in iron-black cubes and massive; G. = 8; contains 11–16 per cent. of silver. The Hartz.

Hessite. Silver telluride, Ag_2Te = Tellurium 37·2, silver 62·8 = 100. Color between lead-gray and steel-gray; sectile; G. = 8·3—8·6; B.B. in the open tube, faint sublimate of tellurous acid; on charcoal with soda a silver globule. The Altai; at Nagyag and Retzbanya;

Coquimbo, Chili; Calaveras Co., Cal.; Red Cloud Mine, Col.; Kearsarge Mine, Dry Cañon, Utah.

Petzite. A hessite with the silver replaced in part by gold. G. = 8·7–9·4. Between steel-gray and iron-black. Variety from Golden Rule Mine afforded Genth Tellurium 32·68, silver 41·86, gold 25·60 = 100·14. Occurs at the same localities with hessite.

Tapalpite. Telluride of bismuth and silver from Mexico.

Sylvanite or *Graphic Tellurium.* Gold-silver telluride (Ag, Au) Te_3 = (if Ag : Au = 1 : 1) Tellurium 55·8, gold 28·5, silver 15·7 = 100. Color and streak steel-gray to silver white, and sometimes nearly brass-yellow; H. = 1·5–2; G. = 7·9–8·33; called *graphic* because of a resemblance in the arrangement of the crystals to writing characters. Transylvania; Calaveras Co., Cal.; Red Cloud, Grand View, and Smuggler Mines, Col.

Stützite. Crystals hexagonal; silver telluride; Ag_4Te? Transylvania.

Eucairite. Silver copper selenide, containing 42–45 per cent. of silver; color between silver-white and lead-gray; easily cut by the knife. From Sweden and Chili.

Dyscrasite, or *Antimonial Silver.* Silver antimonide; contains 78 to 85 parts of silver, and has nearly a tin-white color; G. = 9·4–9·8; B.B. fumes of antimony pass off, leaving finally a globule of silver. Wolfach, Wittichen; Andreasberg; Allemont in Dauphiny; Bolivia, S. A.

Huntilite. A silver arsenide; dark gray to black, amorphous; G. = 7·47. Silver Islet, L. Superior. *Mcfarlanite* is impure huntilite.

Animikite. A silver antimonide. Silver Islet, L. Superior.

Sulpharsenates. Sulphantimonates.

Pyrargyrite.—Ruby Silver. Dark Red Silver Ore.

Rhombohedral. $R \wedge R = 108° 42'$; $R \wedge i\text{-}2 = 129° 39'$. Cleavage parallel to R imperfect. Also massive. Black to dark cochineal-red, with the streak cochineal-red and lustre splendent metallic-adamantine. H. = 2–2·5. G. = 5·7–5·9.

Composition. Ag_3S_3Sb (= $3Ag_2S + Sb_2S_3$) = Sulphur 17·7, antimony 22·5, silver 59·8 = 100.

B.B. fuses very easily; on charcoal a white deposit of antimony oxide, and with soda a globule of silver. In an open tube, sulphurous fumes that redden litmus paper.

Diff. Its red streak, and its reactions for antimony and silver, are distinctive.

Obs. Occurs at Andreasberg; also in Saxony; Hungary; Cornwall; Mexico; Chili; Nevada at Washoe; abundant

about Austin, Reese River; at Poor Man's Lode, and elsewhere, in Idaho; Arizona.

Proustite, or *Light Red Silver Ore*, is a related ore containing arsenic in place of much or all of the antimony, and having a light-red color, splendent lustre; G. = 5·4–5·6. *Composition*, Ag_3S_3As = Sulphur 19·4, arsenic 15·1, silver 65·5 = 100. B.B. gives a garlic odor. Occurs with pyrargyrite at the above-mentioned localities, and in microscopic crystals in Cabarrus Co., N. C.

Stephanite.—Brittle Silver Ore. Black Silver.

Orthorhombic. $I \wedge I = 115° 39'$. No perfect cleavage. Often in compound crystals. Also massive. Streak and color iron-black. H. = 2–2·5. G. = 6·27.

Composition. Ag_5S_4Sb ($= 5Ag_2S + Sb_2S_3$) = Sulphur 16·2, antimony 15·3, silver 68·5. B.B. an odor of sulphur and also fumes of antimony, yielding a dark metallic globule from which silver may be obtained by the addition of soda. Soluble in dilute nitric acid; the solution indicates the presence of silver by silvering a plate of copper.

Obs. Occurs with other silver ores at Freiberg, Schneeberg, and Johanngeorgenstadt, in Saxony; also in Bohemia, and Hungary. An abundant ore in Chili, Peru, and Mexico; also in Nevada, at the Comstock Lode, and at Ophir, and Mexican mines, in the Reese River and Humboldt, and other regions; in Colorado, in Clear Creek Co. and elsewhere; in Idaho; Arizona. Sometimes called *black silver*.

Polybasite. Near stephanite in color, specific gravity, and composition, but contains some arsenic and copper, with 64 to 72·2 per cent. of silver; orthorhombic, and usually in tabular hexagonal prisms, without distinct cleavage; G. = 6·214. Freiberg; Przibram; Mexico; Chili; the Reese mines in Nevada; Idaho; Arizona.

Miargyrite. Antimonial silver sulphide, containing but 36·5 per cent. of silver, and having a *dark cherry-red streak*, though iron-black in color. H. = 2–2·5; G. = 5·2–5·4; B.B. on charcoal gives off fumes of antimony and an odor of sulphur; and in the oxidating flame, a globule is left which finally yields a button of pure silver. Saxony; Bohemia; Spain; Mexico; Arizona.

Brongniardite. In regular octahedrons and massive; color grayish-black; G. = 5·95; contains about 25 per cent. of silver, with lead, antimony, and sulphur. From Mexico.

Polyargyrite. Isometric, having cubic cleavage; near polybasite in composition = $12Ag_2S + Sb_2S_3$. Wolfach in Baden.

Freieslebenite. A monoclinic antimonial silver-lead sulphide; color light steel-gray; G. = 6–6.4; H. = 2–2·5; contains 22 to 24 per cent.

of silver. Saxony; Transylvania; Spain; Arizona. *Diaphorite* is the same in composition, but is orthorhombic.

Pyrostilpnite. Another monoclinic silver ore; in delicate crystals grouped like stilbite; color fire-red. Contains 62·3 per cent. of silver. Freiberg; Andreasberg; Przibram.

Schirmerite. Lead-gray to iron black; contains silver, lead, with much bismuth and sulphur. Red Cloud Mine, Col., and elsewhere.

Chlorides, Bromides, Iodides.

Cerargyrite.—Horn Silver. Silver Chloride.

Isometric. In cubes, with no distinct cleavage. Also massive, and rarely columnar; often incrusting. H. = 2–1·5; G. = 5·3–5·5. Color gray, passing into green and blue; looking somewhat like horn or wax, and cutting like it. Lustre resinous, passing into adamantine. Streak shining. Translucent to nearly opaque.

Composition. Ag Cl = Chlorine 24·7, silver 75·3. Fuses in the flame of a candle, and emits acrid fumes. B.B. affords silver easily on charcoal. A plate of iron rubbed with it is silvered.

Obs. A very common ore and extensively worked in the mines of South America and Mexico; also abundant in Nevada; in Idaho at Poor Man's Lode; in Arizona; Utah; Colorado; in Saxony, Siberia, Norway, the Hartz, and Cornwall. A variety containing mercury occurs at the mine La Julia, Northern Chili.

Bromyrite or *Bromic Silver.* Silver bromide, Ag Br = Bromine 42·6, silver 57·4 = 100; H. = 2–3; G. = 5·8–6. With the preceding, in Mexico and Chili.

Embolite. Silver chlorobromide, resembling cerargyrite; H. = 1–1·5; G. = 5·3–5·8; color asparagus to olive green; contains 51 p. c. of silver chloride to 49 of bromide. Common in Chili; also found in Chihuahua, Mexico.

Iodyrite. Silver iodide, Ag I = Iodine 54·0, silver 46 0 = 100; bright yellow; lustre not metallic, like the preceding; G. = 5·5–5·7. Spain; Chili; Mexico; the Cerro Colorado Mine, Arizona. *Iodobromite* is a yellow brom-iodo-chloride of silver, in octahedrons; from near Nassau.

Tocornalite. A silver-mercury iodide. Chili.

General Remarks.—The chief sources of the silver of commerce are (1) *Native silver;* (2) the sulphide, *Argentite* (or vitreous silver); four species among the sulpharsenites and sulphantimonites, viz., (3) *Proustite,* or the light-red or ruby-silver ore, and (4) *Pyrargyrite,* or dark-red silver ore; (5) *Freieslebenite;* (6) *Argentiferous tetrahedrite,* which contains sometimes 10 to 30 per cent. of silver; (7) *Stephanite* or

brittle silver ore; (8) the chloride, called horn-silver or *Cerargyrite;* (9) the bromide and chlorobromide, *Bromyrite* and *Embolite,* common in Chili and Mexico, especially the latter, along with the rarer iodide; (10) *Argentiferous Galenite,* often called silver-lead ore. Of the other ores of silver mentioned beyond, the most important are *Arquerite,* common especially in Chili, and *Polybasite.*

Silver ores occur in rocks of all ages and kinds, from gneiss, granite, and mica schist, to sandstones, shales, and limestones, and from Archæan to Tertiary. Among the above-mentioned ores, argentiferous galenite, or silver-lead ore, is of very prominent importance, and as both of its metals, the lead and silver, are valuable and the reduction easy, it is worked when containing but five ounces of silver to the ton.

The veins of silver ores in gneiss and metamorphic rocks, away from eruptive kinds, usually have galenite as the chief ore, with sulphides of iron, zinc, and copper as associates, and quartz, and often more or less fluorite or barite, as the gangue. Other silver ores, the sulphides, arsenical and antimonial, may also be present and abundant; yet when so, they are mostly if not wholly secondary products, and are accompanied generally by lead carbonate and sulphate. But in most rich silver regions the veins, whether intersecting metamorphic, fragmental or calcareous formations, are connected with eruptive rocks. Yet even in such cases galenite is usually an abundant vein-material, and may have been a source of much of the silver. Sulphur, arsenic, and antimony have been among the materials introduced, and these agents, together with carbonic acid, phosphoric acid, oxygen and chlorine, derived from below or above, have carried on the changes.

The silver-producing veins of the eastern border of North America are mostly veins in metamorphic rocks having no connection with eruptive rocks, and they have yielded little silver. The Michigan region and those of productive mines in western America over the summit and western slope of the great mountain range from Patagonia to British America are for the most part in regions intersected by eruptive rocks, and to this fact owe their existence. Moreover, excluding the Michigan region, they are much alike, through the five thousand miles, in their characters, their ores, and the associated eruptive rocks. The eruptives are chiefly andesyte, rhyolyte, dacyte, and dolcryte, or basalt. Silver chloride is usually a common ore, especially in the upper part of the veins or deposits; and a mixture of it with more or less of lead carbonate, often with iron oxide (from the decomposition of iron or copper sulphides) and with limestone and other material (from the decomposed rocks), makes the ore called *carbonate.* Other lead ores, the ruby-silver ores, argentite, stephanite, tetrahedrite, and the rest of those above enumerated, are common in the veins. Gold is often present, also copper and zinc ores. Limestone strata are common repositories of the ores; and this is attributed to the fact that limestone is easily eroded by acid solutions and vapors; so that, if intersected by a fissure up which such vapors or solutions are ascending, cavities or chambers will be made in it, and passageways along the joints and seams for the reception of the ore deposits. In the Washoe region, Nevada, and many others, there is

no limestone. The chlorine of the silver chloride is supposed to have come from superficial saline waters, like those of the Great Salt Lake, salt being a sodium chloride; carbonic acid for the lead carbonate, from the limestone; the sulphur, from the decomposition of sulphides, as galenite, pyrite, etc.; the arsenic, antimony, with part of the sulphur, from the ascending vapors; the silver, from ores in the rock making the walls of the fissures somewhere below at large or shallow depths (and argentiferous galenite may have been the most prominent source). Secondary products are still in progress in the surface portion of most veins; and in the deeper, if there is some little heat to favor change.

The richest mines of Chili are not far distant from Copiapo, in the mountains north of the valley of Huasco. The mines of Mt. Chanarçillo, about 16 leagues south of Copiapo, abound in horn silver, and begin to yield arsenio-sulphides at a depth of about 500 feet. The mines of Punta Brava, which are nearer the Cordilleras, afford the arsenical and antimonial ores. In Peru, the principal mines are in the districts of Pasco, Chota, and Huantaya. Those of Pasco are 15,700 feet above the sea, while those of Huantaya are in a low desert plain, near the port of Yquique, in the southern part of Peru. The ores afforded are the same as in Chili. The mines of Huantaya are noted for the large masses of native silver they have afforded. Silver is obtained in Peru, also, in the districts of Caxamarca, Pataz, Huamanchuco, and Hualgayoc. The Potosi mines in Bolivia occur in a mountain of argillaceous shale, whose summit is covered by a bed of argillaceous porphyry. The ore is the ruby silver, and argentite with native silver. The district of Caracoles, between Chili and Bolivia, yields much silver.

In Europe the principal mines are those of Spain, the province of Guadalajara, where the ore is chiefly freieslebenite; of Kongsberg in Norway; of Saxony, chiefly at Freiberg, Ehrenfriedensdorf, Johanngeorgenstadt, Annaberg, and Schneeberg; in the Hartz; in Austria, Hungary, Transylvania, and the Banat; and Russia. The mines of Kongsberg, in Norway, occur in gneiss and hornblende slate, in a gangue of calcite. They were especially rich in native silver.

In the Tyrol, Austria, argentite, argentiferous tetrahedrite, and mispickel occur in a gangue of quartz, in argillaceous schist. The Hungarian mines, at Schemnitz and Kremnitz, occur in syenyte and hornblende porphyry, in a gangue of quartz, often with calcite or barite (heavy spar), and sometimes fluorite. The ores are argentite, tetrahedrite, galenite, blende, pyritous copper and iron; and the galenite and copper ores are argentiferous. France produces some silver from argentiferous galenite at Huelgoet in Brittany, and the mines of Pontgibaud, Puy-de-Dome.

The Russian mines are in Kolyvan in the Altai, and Nertschinsk in the Daouria Mountains, Siberia (east of Lake Baikal). The Daouria mines afford argentiferous galenite which is worked for its silver; it occurs in a crystalline limestone. The silver ores of the Altai occur in Silurian schists in the vicinity of porphyry, which contain also gold, copper, and lead ores.

The mines of Mexico are most abundant between 18° and 24° north

latitude, on the back or sides of the Cordilleras, and especially the west side; and the principal are those of the districts of Guanaxuato, Zacatecas, Fresnillo, Sombrerete, Catorce, Oaxaca, Pachuca, Real del Monte, Batopilas, and Tasco. The vein of Guanaxuato, the most productive in Mexico, intersects argillaceous and chloritic shale, and porphyry; it affords one fourth of all the Mexican silver. The Valencian mine is the richest in Guanaxuato. The Pachuca, Real del Monte, and Moro districts are near one another.

In the United States the chief silver mines are in Colorado, Nevada, Utah, New Mexico, Arizona, Montana, Idaho. For regions, see List of Localities, beyond. The copper mines of northern Michigan afford much native silver, and also the native gold of the various gold mines of the country.

For the years previous to 1859 the whole yield of silver from the United States mines is estimated at $1,000,000. The following are the amounts for the succeeding years to 1870:

1859	$100,000	1865	$11,250,000
1860	150,000	1866	10,000,000
1861	2,100,000	1867	13,550,000
1862	4,500,000	1868	12,000,000
1863	8,500,000	1869	13,000,000
1864	11,000,000	1870	17,320,000

The Comstock lode, in the Washoe region, Nevada, was first opened in 1859, and contributed to the silver of the world, in 1860, about $1,000,000. Virginia City grew out of it. In 1861 other mining regions were discovered in Humboldt Co., 150 miles north-east of Virginia City, and in 1862 the Reese River discoveries (at the present town of Austin) were made; others soon followed, among which, those in the Eureka district, 60 miles east of Austin, have proved of great value. Nevada Territory in 1875 yielded of silver $14,922,350, and in 1876, $20,570,078. The amount fell off in 1878, owing to the working out of the Comstock lode, and in 1882 it was only $6,750,000.

For the yield of the United States in silver since 1870, see page 127.

The yield of the Western States and Territories in 1876 and 1884 is reported as follows:

	1876.	1884.
Arizona	$500,000	$4,500,000
California	1,800,000	3,000,000
Colorado	3,000,000	16,000,000
Dakota	.....	150,000
Idaho	300,000	2,720,000
Montana	800,000	7,000,000
Nevada	20,570,078	5,600,000
New Mexico	400,000	3,000,000
Oregon	.....	20,000
Utah	3,351,520	6,800,000
Washington	.....	1,000

In the Report of the U. S. Mint for 1885 the yield of the world in 1884 is given approximately, as follows:

Norway and Sweden	$340,962
Austria-Hungary	2,054,070
Germany	10,311,659
Russia	388,000
France	264,275
Italy	17,949
Spain	148,000
Turkey	89,916
Australia	115,960
Japan	877,772
Peru	1,908,000
Bolivia	16,000,000
Chili	5,325,000
Argentine Republic	420,225
Colombia	760,000
Mexico	27,257,885
United States	48,800,000
Canada	68,205
Total	$115,147,878

The following table gives, in dollars, the estimated value of the world's production of silver in recent years:

	Russia.	United States.	Mexico and S. America.	Other Countries.	Total.
1855...	600,000	.....	30,000,000	10,000,000	40,600,000
1860...	650,000	150,000	30,000,000	10,000,000	40,800,000
1865...	700,000	11,250,000	30,000,000	10,000,000	51,950,000
1870 ..	575,000	17,320,000	25,000,000	10,000,000	57,895,000
1875...	500,000	31,635,000	25,000,000	10,000,000	67,135,000
1882...	324,000	46,800,000	48,651,000	16,000,000	111,775,000
1884...	388,000	48,800,000	51,740,000	14,222,000	115,150,000

The world's production of silver from 1800 to 1830 is estimated at $799,100,000 (average $26,637,000); from 1830 to 1851, inclusive, at $600,400,000 (average $27,300,000); from 1852 to 1877, twenty-six years, $1,341,800,000 (average $51,608,000); from 1882 to 1884, inclusive, $343,893,000 (average $114,631,000).

The relative value of silver and gold, about 1500, was 1:11·25; 1600, 1:12; 1700, 1:15; 1800, 1:15; 1820, 1:15·5; 1840, 1:15·75; 1860, 1:15·35; 1875, 1:16; 1878, 1:18; 1879, 1:18·4; 1886, 1:20. Herodotus made the ratio 1:13; Plato, 1:12; Menander, 1:10; and in Cæsar's time it was 1:9.

Native Platinum.

Isometric: but crystals seldom observed. Usually in flattened or angular grains or irregular masses. Cleavage none.

Color and streak pale or dark steel-gray. Lustre metallic, shining. Ductile and malleable. H. = 4–4·5. G. = 16–19; 17·108, small grains; 17·608, a mass. (When pure, 21·15.) Often slightly magnetic, and some masses will take up iron filings.

Composition. Platinum is usually combined with more or less of the rare metals iridium, rhodium, palladium, and osmium, besides copper and iron, which give it a darker color than belongs to the pure metal and increase its hardness. A Russian specimen afforded: Platinum 78·9, iridium 5·0, osmium and iridium 1·9, rhodium 0·9, palladium 0·3, copper 0·7, iron 11·0 = 98·75. California platinum afforded: Platinum 85·50, iridium 1·05, osmiridium 1·10, rhodium 1·00, palladium 0·60, copper 1·40, iron 6·75 ; but some of California yields only 50 per cent. of platinum.

Platinum is soluble in heated aqua regia. It is one of the most infusible substances known, being B.B. unaltered. Slightly magnetic, and this quality is increased by the iron it may contain.

Diff. Platinum is at once distinguished by its malleability, specific gravity, and extreme infusibility.

Obs. Platinum was first detected in 1735 in grains in the alluvial deposits of Choco and Barbaçoa in New Granada (now U. States of Colombia), within two miles of the northwest coast of South America, where it received the name *platina*, derived from the word *plata*, meaning *silver*. Although before known, an account by Ulloa, a Spanish traveller in America in 1735, directed attention in Europe, in 1748, to the metal. It is now obtained in Novita, and at Santa Rita and Santa Lucia, Brazil. It has been afforded most abundantly by the Urals. It occurs also on Borneo; in the sands of the Rhine; in Australia; in those of the river Jocky, St. Domingo; in traces in the U. States, in Rutherford Co., N. Carolina; Virginia; Georgia; at La François Beauce, Canada; with gold near Point Orford, on the coast of Northern California (probably derived, according to W. P. Blake, from serpentine rocks); Wood R. Co., Idaho; in British Columbia. A nugget, of

104·4 grams, found near Plattsburgh, N. Y., afforded Collier 46 p. c. of platinum and 54 p. c. of chromite, and had G. = 10·446.

The Ural localities of Nischne Tagilsk and Goroblagodat have afforded much the larger part of the platinum of commerce. It occurs, as elsewhere, in alluvial beds; but the courses of platiniferous alluvium have been traced to a great extent up Mount La Martiane, which consists of crystalline rocks, and is the origin of the detritus. *One* to *three* pounds are procured from 3700 pounds of sand. The production of the U. States in 1884 was not over 150 troy ounces.

Though commonly in small grains, masses of considerable size have occasionally been found. A mass weighing 1088 grains was brought by Humboldt from South America and deposited in the Berlin Museum. Its specific gravity was 18·94. In the year 1822, a mass from Condoto was deposited in the Madrid Museum, measuring 2 inches and 4 lines in diameter, and weighing 11,641 grains. A more remarkable specimen was found in the year 1827 in the Urals, not far from the Demidoff mines, which weighed 11·57 pounds troy; and similar masses are now not uncommon. The largest hitherto discovered weighed 21 pounds troy.

Russia has afforded annually about 35 cwt. of platinum, which is about five times the amount from Brazil, Borneo, Colombia, and St. Domingo. Borneo affords about 500 pounds per year.

The infusibility of platinum and its resistance to the action of the air, and moisture, and most chemical agents, renders it of great value for the construction of chemical and philosophical apparatus. The large stills employed in the concentration of sulphuric acid are now made of platinum; but such stills are gilt within, since platinum when unprotected is acted upon by the acid, and soon becomes porous. It is also used for crucibles and capsules in chemical analysis; for galvanic batteries; as foil, or worked into cups or forceps, for supporting objects before the blowpipe. It alloys readily when heated with iron, lead, and several of the metals, and is also attacked by caustic potash and phosphoric acid, in contact with carbon; and consequently there should be caution when heating it not to expose it to these agents.

It is employed for coating copper and brass; also for

painting porcelain and giving it a steel lustre, formerly highly prized. It admits of being drawn into wire of extreme tenuity.

Platinum was formerly coined in Russia. The coins had the value of 11 and 22 rubles each.

This metal fuses readily before the "compound blowpipe;" and Dr. Hare succeeded in 1837 in melting twenty-eight ounces into one mass. The metal was almost as malleable and as good for working as that obtained by the other process; it had a specific gravity of 19·8. He afterwards succeeded in obtaining from the ore masses which were 90 per cent. platinum, and as malleable as the metal in ordinary use, though somewhat more liable to tarnish, owing to some of its impurities. Deville and Debray have perfected this process, and have melted over 25 pounds of platinum in less than three quarters of an hour. In the process the osmium present is oxidized and thus removed.

Platin-iridium. Grains of iridium have been obtained at Nischne Tagilsk, consisting of 76·8 iridium and 19·64 platinum, with some palladium and copper. A similar platin-iridium has been obtained at Ava, in the East Indies. Another, from Brazil, contained 27·8 iridium, 55·5 platinum, and 6·9 rhodium. Reported from Mendocino and Trinity Cos., Cal.

Iridosmine. A compound of iridium and osmium from the platinum mines of Russia, South America, the East Indies, and California; in pale steel-gray hexagonal prisms, but usually in flat grains; H. = 6·7; G. = 19·5–21·1; malleable with difficulty. One variety, called *Nefdanskite*, contains iridium 46·8, osmium 49·3, rhodium 3·2, iron 0·7. Another, *Sisserskite*, iridium 25·1, osmium 74·9, and iridium 20, osmium 80. But analysis affords also from 0·5 to 12·3 of rhodium, and 0·2 to 6·4 of the rarer metal *ruthenium*, with traces usually of platinum, copper, and iron. The grains are distinguished from those of platinum by their superior hardness, and also by the peculiar odor of osmium when heated with nitre. Iridosmine is common with the gold of Northern California, and injures its quality for jewelry. Occurs sparingly in the gold washings on the rivers Du Loup and Des Plantes, Canada.

The metal iridium is extremely hard, and is used, as well as rhodium, for points to the nibs of gold pens, for the knife-edges of fine balances, etc. The standard meters of the International Commission on Weights and Measures consist of 90 per cent. of platinum and 10 of iridium.

Laurite. In minute octahedrons. A ruthenium sulphide, with 3 per cent. of osmium. From platinum sands of Borneo and Oregon.

Palladium.

Isometric. In minute octahedrons. Occurs mostly in grains, sometimes composed of divergent fibres. Color

steel-gray, inclining to silver-white. Ductile and malleable. H. = 4·5–5. G. = 11·3–12·2 (the latter after hammering).

Consists of palladium, with some platinum and iridium. Fuses with sulphur, but not alone.

Obs. Occurs in Brazil with gold, and is distinguished from platinum, with which it is associated, by the divergent structure of its grains. It was discovered by Wollaston, in 1803. *Selenpalladite*, or *Allopalladium*, is from Tilkerode in the Hartz; reported also from St. Domingo and the Urals. *Porpezite* is palladium gold, or gold containing 7 to 11 per cent. of palladium.

This metal is malleable, and when polished has a whitish steel-like lustre which does not tarnish. A cup weighing 3¼ pounds was made by M. Bréant in the mint at Paris, and is now in the *garde-meuble* of the French crown. In hardness it is equal to fine steel. 1 part fused with 6 of gold forms a white alloy; and this compound was employed, at the suggestion of Dr. Wollaston, for the graduated part of the mural circle constructed by Troughton for the Royal Observatory at Greenwich. Palladium has been employed also for certain surgical instruments.

MERCURY.

Mercury occurs native; alloyed with silver forming native amalgam; in combination with sulphur, selenium, chlorine, or iodine; and with sulphur and antimony in some tetrahedrite. Its ores are completely volatile, excepting when silver or copper is present.

Native Mercury, or Quicksilver.

Isometric. In fluid globules scattered through the gangue. Color tin-white. G. when pure = 13·58. Becomes solid and crystallizes at a temperature of − 39° F., and then G. = 14·4–14·5.

Mercury, or quicksilver, as it is often called (a translation of the old name "argentum vivum"), is entirely volatile B.B., and dissolves readily in nitric acid.

Obs. Occurs at the different mines of this metal, at Almaden in Spain, Idria in Carniola (Austria), in Hungary, Peru, California, and Colorado. Usually in disseminated

globules, but sometimes accumulated in cavities so as to be dipped up in pails.

Used for the extraction of gold and silver ores. Also employed for silvering mirrors, for thermometers and barometers, and for various purposes connected with medicine and the arts.

Native Amalgam. See page 130.

Cinnabar.—Mercury Sulphide.

Rhombohedral; $R \wedge R = 72° 36'$. Cleavage lateral, highly perfect. Crystals often tabular, or six-sided prisms. Also massive; sometimes in earthy coatings.

Lustre unmetallic, of crystals adamantine; often dull. Color bright red to brownish red, and brownish black. Streak scarlet-red. Subtransparent to nearly opaque. H. = 2–2·5. G. = 9; impure, 8·5 and less. Sectile.

Composition. HgS_2 = Sulphur 13·8, mercury 86·2. Often impure. The *liver ore*, or *hepatic cinnabar*, contains some carbon and clay, and has a brownish streak and color. B.B. volatilizes entirely when pure.

Diff. Distinguished from red oxide of iron and chromate of lead by vaporizing B.B.; from realgar by alliaceous fumes on charcoal.

Obs. The ore from which the principal part of the mercury of commerce is obtained. When pure identical with the pigment *vermilion*. Occurs mostly in connection with siliceous, hydromica, and argillaceous slates, or other stratified deposits, both the most ancient and those of more recent date. Too volatile to be expected in any abundance in proper igneous or highly crystalline rocks, yet has been found sparingly in granite.

The localities are mentioned beyond.

Metacinnabarite. The same compound as cinnabar, but different in crystallization. Redington Mine, Lake Co., Cal. *Guadalcazarite*, from Mexico, is a variety.

Tiemannite. Dark steel-gray mercury selenide. The Hartz; vicinity of Clear Lake, Cal., and Utah.

Onofrite. Massive, blackish-gray, metallic; G. = 7·62; mercury sulpho-selenide. San Onofre, Mexico; Marysvale, Utah.

Coloradoite. Grayish-black mercury telluride; G. = 8·627. Keystone and Mountain Lion and Smuggler Mines, Col.

Calomel or *Horn Quicksilver.* Mercury chloride; tough, sectile; light yellowish or grayish; lustre adamantine; translucent or sub-

translucent; H. = 1–2; G. = 6·48; contains 15·1 per cent. of chlorine and 84·9 of mercury. Spain.

Iodic Mercury. Mercury iodide; reddish brown. Mexico.

Magnolite. Mercury tellurate, in white, silky radiating tufts; Hg_2O_4Te. Magnolia District, Col.

Barcenite. Gray to black, earthy lustre; H. = 5·5; G. = 5·343; an antimonate containing 20·75 per cent. of mercury. Mexico.

General Remarks.—The following are the regions of the principal mines of mercury. At Idria, in Austria (discovered in 1497), where the ore is a dark bituminous cinnabar distributed through a blackish shale or slate, containing some native mercury; at Almaden, in Spain, near the frontier of Estremadura, in the province of La Mancha, in argillaceous beds and grit rock, which are intersected by dikes of "black porphyry" and granite—mines mentioned by Pliny as affording vermilion to the Greeks, 700 years before the Christian era; in the Palatinate on the Rhine; in Hungary; Sweden; France; Ripa, in Tuscany; region of the Don, in Russia; in Shensi, in China; at Arqueros, in Chili; at Huanca Velica, and some other points in Peru; at St. Onofre and other places in Mexico; in California.

The most noted of the California mines, New Almaden, is situated in Mine Hill, Santa Clara Co., south of San Francisco. The rocks are altered Cretaceous slates, talcose in part, with beds of serpentine either side, and associated also with beds of jasper or siliceous slate. The New Idria mine is in Fresno Co., in the Mt. Diablo Range, and was discovered in 1855. The rocks are more or less altered silico-argillaceous and siliceous slates and sandstones, and the cinnabar is distributed irregularly through them; between this and the Aurora Mine on San Carlos (the highest peak of the Diablo Range, 4977 feet), there is much serpentine (in which is chromic iron) and siliceous rock or slate. In Napa Valley, Napa Co., north of San Francisco, there are other valuable mines situated in rocks closely similar, as Whitney states, to those affording quicksilver at New Almaden. They are in a serpentine belt, the cinnabar being in some places in the serpentine, but mostly in the peculiar siliceous rock associated with it. Native mercury occurs with the cinnabar. There are mines also in Lake Co.

The product of the California mines of mercury in 1874 was 34,254 flasks (a flask in California = 76½ lbs), or over 2,600,000 lbs.; in 1881, 60,851 flasks; in 1884, 31,913 flasks. About two thirds of the amount in 1884 was from the New Almaden mine. The yield of the Almaden mine, Spain, in 1884, was about 43,100 flasks, and that of the Idria mine, Austria, 13,000. The other foreign mines produce but little. The price in 1884 was 20 to 35 dollars per flask, or 34 to 46 cents per pound.

COPPER.

Copper occurs native; also combined with oxygen, sulphur, selenium, arsenic, antimony, chlorine; and as carbonate, phosphate, arsenate, nitrate, sulphate, vanadate, and silicate. The ores of copper vary in specific gravity from 3·5 to 8·5, and seldom exceed 4 in hardness.

Native Copper.

Isometric. In octahedral, dodecahedral, and other forms, often much distorted; no cleavage apparent. Also in plates or masses, and in large or small arborescent and filiform shapes, consisting usually of a string of crystals.

Color copper-red. Ductile and malleable. H. = 2·5–3. G. = 8·8–8·95; when pure 8·91–8·95.

Often contains a little disseminated silver. B.B. fuses readily, and, on cooling, covered with the black oxide. Dissolves in nitric acid, and produces a deep azure-blue solution on the addition of ammonia. Fuses at 1930° F.

Obs. Native copper accompanies ores of copper, and usually occurs in the vicinity of dikes of igneous rocks.

Siberia, Cornwall, and Brazil are noted for the native copper they have produced. A mass, supposed to be from Bahia, now at Lisbon, weighs 2616 pounds. South of Lake Superior about Portage Lake on Keweenaw Point, and also, less abundantly, on the Ontonagon River, and at some other points in that region, native copper occurs mostly in veins in trap, and also in the enclosing sandstone. A mass weighing 3704 lbs. has been taken from thence to Washington City; it is the same that was figured by Schoolcraft, in the *American Journal of Science,* volume iii., p. 201. One large mass was quarried out in the "Cliff Mine," whose weight has been estimated at 200 tons. It was 40 feet long, 6 feet deep, and averaged 6 inches in thickness. This copper contains, intimately mixed with it, about $\frac{3}{10}$ per cent. of silver. Besides this, perfectly pure silver, in strings, masses, and grains, is often disseminated through the copper, and some masses, when polished, appear sprinkled with large white spots of silver, "resembling a porphyry with its feldspar crystals." Crystals of native copper are also found penetrating masses of prehnite and analcite in the trap rock. This mixture of copper and silver cannot be imitated by art, as the two metals form an alloy when melted together. It is probable that the separation in the rocks is due to the cooling from fusion being so extremely gradual as to allow the two metals to solidify separately, at their respective temperatures of solidification—the trap being an igneous rock, and ages often elapsing, as is well known, during the cooling of a bed of lava when covered from the air. Native copper occurs sparingly on St. Ignace and Michipicoten Islands, Lake Superior.

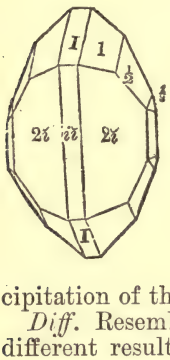
Small specimens of native copper have been found in the States of New Jersey, Connecticut, and Massachusetts, where the Triassic formation occurs. One mass from near Somerville, N. J., weighs 78 pounds, and is said originally to have weighed 128 pounds. Within a few miles to the north of New Haven, Conn., one mass of 90 pounds, and another of 200, besides other smaller, have been found in the drift, all of which came from veins in the trap or associated Triassic sandstone.

Native copper occurs also in South Australia; it is stated that a single train from the Moonta Mine carried away at one time forty tons of native copper.

Sulphides, Selenides, Arsenides.

Chalcocite.—Copper Glance. Vitreous Copper Ore. Redruthite.

Orthorhombic; $I : I = 119° 35'$. Cleavage parallel to *I*, but indistinct. Also in compound crystals like aragonite. Often massive.



Color and streak blackish lead-gray; often tarnished blue or green. Streak sometimes shining. H. = 2·5–3. G. = 5·5–5·8.

Composition. Cu_2S = Sulphur 20·2, copper 79·8 = 100. B.B. on charcoal gives off fumes of sulphur, fuses easily in the exterior flame; and after the sulphur is driven off, a globule of copper remains. Dissolves in heated nitric acid, with a precipitation of the sulphur.

Diff. Resembles argentite, but is not sectile, and affords different results B.B. The solution in nitric acid covers an iron plate (or knife-blade) with copper, while a similar solution of the silver ore covers a copper plate with silver.

Obs. Occurs with other copper ores in beds and veins. At Cornwall, splendid crystallizations; also in Siberia; Hesse; Saxony; the Banat; Chili, etc.

In the United States, a vein formerly affording fine crystallizations occurs at Bristol, Ct. Other localities are at Wolcottville, Simsbury, and Cheshire, Ct.; at Schuyler's Mines, and elsewhere, N. J.; in the U. S. copper-mine district, Blue Ridge, Orange County, Va.; between New Market and Taneytown, Md.; and sparingly at the copper

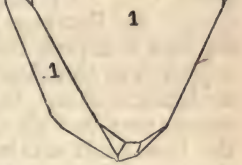
mines of Michigan and the Western States; also at some mines north of Lake Huron; in the San Juan and other mining regions in Colorado; in New Mexico, in Socorro and Grant Cos.; in Arizona; at the Bruce Mines, Lake Huron, and at Prince's Mine, Spar Island, and on Michipicoten Island, Lake Superior.

Covellite, or *Blue Copper*. Massive; dull blue-black; the composition CuS; G. = 3·8; contains 66·5 per cent of copper.

Harrisite. Chalcocite with *cubic* cleavage. Canton Mine, Ga.

Chalcopyrite.—Copper Pyrites. Copper and-Iron Sulphide.

Tetragonal; $1 \wedge 1 = 109° 53'$, and $108° 40'$. Crystals tetrahedral or octahedral; sometimes compound. Cleavage indistinct. Also massive, and of various imitative shapes.



Color brass-yellow, often tarnished deep yellow, and also iridescent. Streak unmetallic, greenish black, and but little shining. H. = 3·5–4. G. = 4·15–4·3.

Composition. $CuFeS_2$ = Sulphur 34·9, copper 34·6, iron 30·5 = 100. Fuses B.B. to a magnetic globule; gives sulphur fumes on charcoal. With soda on charcoal, a globule of metallic iron with copper. The usual effect with nitric acid.

Diff. Resembles native gold in color, and also pyrite. Distinguished from gold by crumbling under a knife, instead of separating in slices; and from pyrite in its deeper yellow color, and in yielding easily to the point of a knife, instead of striking fire with a steel.

Obs. Occurs in veins intersecting gneiss and other metamorphic rocks; also in those connected with eruptive rocks; and sometimes in cavities or veins in ordinary stratified rocks. Usually associated with pyrite, and often with galenite, blende, and copper carbonates. The copper of Fahlun, Sweden, is obtained mostly from this ore, where it occurs with serpentine in gneiss. Other mines of this ore are in the Hartz, near Goslar; in the Banat, Hungary, Thuringia, etc. The Cornwall ore is mostly of this kind. As prepared for sale at Redruth it rarely yields 12 per cent., and generally only 7 or 8, and occasionally as little as 3 to 4 per cent.

of metal; "6½ per cent. of metal may be considered an average of the produce of the total quantity of ore sold." (Phillips, 1874.) Such poverty of ore is only made up by its facility of transport, the moderate expense of fuel, or the convenience of smelting. Its richness may generally be judged of from the color: if of a fine yellow hue, and yielding readily to the hammer, it is a good ore; but if hard and pale yellow it contains much pyrite, and is of poor quality.

In the U. States it occurs at Ely and Strafford, Vt.; at Shrewsbury, Corinth, Waterbury, Vt.; also in New Hampshire, Maine, Massachusetts, and Connecticut; at the Ancram lead mine, N. Y.; also near Rossie, and at Wurtzboro', N. Y.; at Morgantown, Pa.; at the Phenix copper mines, Fauquier Co , and at the Walton gold mine, Luzerne Co., Va.; Liberty and New London in Frederick Co., at the Patapsco mines near Sykesville, Md.; in Davidson and Guilford Cos., N. C. In Michigan, where native copper is so abundant, a rare ore; occurs at Presqu'isle, and at Mineral Point, in Wisconsin, where it is the predominating ore; in Polk Co., at the Hiwassee mines, Tenn.; in the San Juan mining region, Col.; in Lander Co., and elswhere, Nev.; in New Mexico; Arizona; Idaho; Utah; at Copperopolis, Calaveras Co., Cal.; also at the Bruce and other mines on Lake Huron; and Michipicoten Islands, in Lake Superior.

Cubanite is a copper-and iron sulphide, containing Sulphur 39·0, iron 38·0, copper 19·8, silica 2·3 = 99·12. Cuba.

Bornite.—Erubescite. Variegated Copper Pyrites.

Isometric; in octahedrons and dodecahedrons. Cleavage octahedral in traces. Also massive.

Color between copper-red and pinchbeck-brown; but tarnishes rapidly on exposure. Streak pale grayish black and but slightly shining. Brittle. H. = 3. G. = 4·4–5·5.

Composition. Cu_3FeS_3 = Sulphur 28·6, copper 55·58, iron 16·36; but varies much. The ore of Bristol, Ct., afforded Sulphur 25·83, copper 61·79, iron 11·77 = 99·39.

B.B. on charcoal fuses to a brittle globule attractable by the magnet; dissolves in nitric acid, with separation of sulphur.

Diff. Distinguished from the preceding by its pale red-

dish-yellow color, and its rapidly tarnishing and becoming of bluish and reddish shades of color, the quality to which the name *erubescite*, from the Latin word for *to blush*, alludes.

Obs. Occurs, with other copper ores, in granitic and allied rocks, and also in stratified formations. The mines of Cornwall have afforded crystallized specimens, and it is there called, from its color, "horse-flesh ore." Other foreign localities of massive varieties are Ross Island, Killarney, Ireland; Norway, Hessia, Silesia, Siberia, and the Banat.

Fine crystallizations were formerly obtained at the Bristol copper mine, Ct., in granite; and also in red sandstone, at Cheshire, in the same State, with malachite and barite. Massive varieties occur at the New Jersey mines, and in Pennsylvania.

Crookesite. Copper selenide containing 17·25 per cent. of thallium, and a little silver. Norway.

Domeykite. White to pinchbeck-brown metallic; H. = 3–3·5; G. = 7–7·5; copper arsenide, Cu_3As_2 = Arsenic 28·3, copper 71·7 = 100. Chili; Portage Lake; Michipicoten Island, L. Superior. *Algodonite* is Cu_6As_2. *Whitneyite* is Cu_9As_2, and is from Houghton Co., Mich.; Sonora.

Berzelianite is a copper selenide; *Eucairite*, a copper-and-silver selenide.

Sulpharsenites, Sulphantimonites, and Sulphobismuthites.

These species include—of Sulpharsenites: *Enargite*, *Binnite*, *Tennantite*, *Lautite*, *Clarite*, *Xanthoconite*; of Sulphantimonites: *Tetrahedrite*, *Polybasite* (p. 133), *Chalcostibite*, *Guejarite*, *Stylotypite*, *Bournonite* (Wheel Ore), *Famatinite*; of Sulphobismuthites: *Aikinite* (p. 164), *Emplectite*, *Chiviatite*, *Wittichenite*.

Enargite. Orthorhombic; grayish iron-black; H. = 3; G. = 4·34–4·45; never fibrous; contains 46–50 p. c. of copper. Morococha, Peru; Chili (*Guayacanite*); Brewster's gold mine, S. C.; Morning Star mine, Alpine Co., Cal.; in Gilpin and San Juan Cos., Col.

Famatinite, from Peru and Arg. Republic, is an antimonial enargite in composition; color grayish copper-red; G. = 4·57.

Binnite. In isometric crystals. Valley of Binnen.

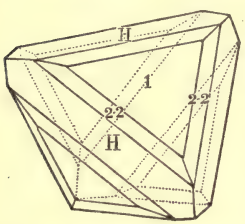
Tennantite. In dodecahedrons; color and streak lead-gray to iron-black; contains some iron with the copper. Cornwall; Norway; Capelton, Quebec.

Fredericite is a variety from Sweden, containing 2·87 p. c. of silver; and *Sandbergerite*, one containing zinc, from Peru.

Tetrahedrite. Gray Copper. Fahlerz.

Isometric; in tetrahedral crystals. Steel-gray to blackish, and streak nearly the same, to brown and cherry-red. H. = 3–4·5. G. = 4·7–5; but the mercuriferous, 5·1–5·6.

Composition. $4CuS + Sb_2S_3$. Part of the copper often replaced by iron and zinc, and sometimes by silver or mercury, and part of the antimony by arsenic, or rarely bismuth; the *argentiferous* (*Freibergite*) sometimes contains 30 p. c. of silver, and the *mercuriferous* (*Schwatzite*) 15 to 18 p. c. of mercury; a kind from Spain contained 10 p. c. of platinum, and one from Hohenstein some gold; another (named *Malinowskite*) 9 to 13 p. c. of lead and 10 to 13 of silver. The Arkansas mineral afforded on analysis, Sulphur 26·71, antimony 26·50, arsenic 1·02, copper 36·40, iron 1·89, zinc 4·20, silver 2·30 = 99·02.



From Cornwall; Andreasberg, Hartz; Kremnitz, Hungary; Freiberg, Saxony; Kapnik, Transylvania; Dillenburg, Nassau; Huallanca, Peru, at a height of 14,700 feet; Mexico, at Durango, etc.; Mariposa and Shasta Co., Cal.; Sheba and De Soto mines, Humboldt Co. and near Austin, Nev.; Heintzelman mine, Santa Rita mine, etc., Arizona; Socorro Co., New Mexico; Gilpin and Clear Summit, Hinsdale and San Juan Cos., Col., a common silver ore; Idaho; Utah; N. of Little Rock, Kellogg mines, Ark.

Frigidite is a *nickeliferous* variety from the Apuan Alps.

Chiviatite. Foliated massive; lead-gray; contains 60 p. c. of bismuth. Peru.

Wittichenite (*Cupreous Bismuth*). Orthorhombic, massive; steel-gray; contains 40 to 50 p. c. of bismuth, and 30 to 35 of copper.

Oxides. Chlorides.

Atacamite.—Copper Oxichloride.

Orthorhombic; in rhombic prisms and other forms; also granular massive. Color green to blackish green. Lustre adamantine to vitreous. Streak apple-green. Translucent to subtranslucent. H. = 3–3·5. G. = 3·76–3·9. *Composition,* $CuCl_2 + 3CuO_2H_2$ = Chlorine 16·64, oxygen 11·25, copper 11·25, water 12·66 = 100. From the Atacama

desert, between Chili and Peru, and elsewhere in Chili; Bolivia; Vesuvius; Saxony; Spain; Cornwall; N. S. Wales.

Cuprite.—Red Copper Ore.

Isometric. In regular octahedrons, and modified forms of the same. Cleavage octahedral. Also massive, and sometimes earthy. Color deep red, of various shades.

1.

2.

3.

Streak brownish red. Lustre adamantine or submetallic; also earthy (*tile ore*). Subtransparent to nearly opaque. Brittle. H. = 3·5–4. G. = 5·99; 5·85–6·15.

Composition. Cu_2O = Oxygen 11·2, copper 88·8. B.B. on charcoal, a globule of copper. Dissolves in nitric acid.

Diff. Differs from cinnabar in not being volatile B.B.; from hematite in yielding a bead of copper on charcoal, and in copper reactions.

Obs. Occurs with other copper ores in the Banat, Thuringia, Cornwall, at Chessy near Lyons, in Siberia, and Brazil. The octahedrons are often green, from a coating of malachite. In the U. States, occasionally crystallized and massive at Schuyler's, Somerville, and the Flemington copper mines, N. J.; near New Brunswick, N. J.; at Bristol, Ct.; near Ladenton, Rockland Co., N. Y.; in the Lake Superior region; in Arizona; N. Mexico; Utah; Wyoming.

Melaconite, or *Black Copper.* Oxide of copper, CuO; a black powder, and in dull black masses and botryoidal concretions, along with other copper ores. Abundant in some of the copper mines of the Mississippi Valley, and yields 60 to 70 per cent. of copper. Results from the decomposition of the sulphides and other ores. At the Hiwassee Mine, Polk Co., Tennessee, it has been abundant. Formerly found of excellent quality in the Lake Superior copper region.

Tenorite. A like oxide, occurring in black flexible, metallic scales on lavas. Vesuvius. *Atelite* is an oxichloride pseudomorph after tenorite.

Eriochalcite. A copper chloride. Vesuvius.

Melanothallite. Copper chloride. Vesuvius, eruption of 1870.

SULPHATES. TUNGSTATES.

Chalcanthite.—Blue Vitriol. Sulphate of Copper.

Triclinic. In oblique rhomboidal prisms. Also as an efflorescence or incrustation, and stalactitic.

Color deep sky-blue. Streak uncolored. Subtransparent to translucent. Lustre vitreous. Soluble, taste nauseous and metallic. H. = 2–2·5. G. = 2·21.

Composition. $CuO_4S + 5$ aq (or $CuO + SO_3 + 5$ aq) = Sulphuric acid (or sulphur trioxide) 32·1, copper oxide 31·8, water 36·1. A polished plate of iron in solutions becomes covered with copper.

Obs. Occurs with the sulphides of copper as a result of their decomposition, and is often in solution in the waters flowing from copper mines. In the Hartz; at Fahlun in Sweden; Rio Tinto mine, Spain; Copiapo, Chili; Hiwassee copper mine, Tenn.; Canton mine, Ga.; in Arizona.

Blue vitriol is much used in dyeing, and in the printing of cotton and linen; also for various other purposes in the arts. It has been employed to prevent dry rot, by steeping wood in its solution; and it is a powerful preservative of animal substances, they remaining unaltered when imbued with it and dried. Afforded by the decomposition of chalcopyrite in the same manner as green vitriol from pyrite; but it is manufactured for the arts chiefly from old sheathing-copper, copper turnings, and copper refinery scales.

In Frederick Co., Md., blue vitriol is made from a black earth which is an impure oxide of copper with copper pyrites.

In some mines, the solution of sulphate of copper is so abundant as to afford considerable copper, which is obtained by immersing clean iron in it, and is called *copper of cementation*. At the copper springs of Wicklow, Ireland, about 500 tons of iron were laid at one time in the pits; in about 12 months the bars were dissolved, and every ton of iron yielded a ton and a half, and sometimes nearly two tons, of a precipitated reddish mud, each ton of which produced 16 cwt. of pure copper. The Rio Tinto Mine in Spain is another where the sulphate in solution is thus utilized; the waters yield annually 1880 cwt. of copper, and consume 2400 cwt. of iron.

Anhydrous Copper Sulphates.—Dolerophanite. Monoclinic; brown; Cu_2O_2S. Vesuvius.

Hydrocyanite. Orthorhombic; green, brownish, sky-blue; *soluble.* Vesuvius.

Hydrous Copper Sulphates.—Brochantite. Orthorhombic, tabular; color emerald-green; G. = 3·8–3·9. Urals; Cornwall; Mexico; Chili; Australia. *Krisuvigite* and *Konigite* are the same.

Langite. Orthorhombic; fine blue, greenish; G. = 3·48–3·5; Cornwall.

Cyanotrichite (Velvet Ore). Velvet like; smalt-blue to sky-blue. Moldawa.

Arnimite. Monoclinic; green; Planitz, Bohemia. *Herrengrundite* (*Urvölgyite*) is a similar copper sulphate, but contains some lime; emerald-green. Hungary.

Hydrous Copper-sodium Sulphate.—Krönkite. Azure-blue. Bolivia.

Hydrous Copper-iron Sulphate.—Philippite. Azure-blue; astringent. Chili.

Anhydrous Copper-zinc Sulphate (?).—*Serpierite.* Orthorhombic, greenish, bluish. Laurium, Greece.

Sulphato-chloride.—Connellite. Hexagonal; fine blue. Cornwall.

Copper-potassium sulphato-chloride.—Chlorothionite. Bright blue; soluble. Vesuvius.

Copper Tungstates.—Cuprotungstite. In yellowish-green crusts. Santiago, Chili.

Phosphates, Arsenates, Vanadates, Nitrate.

Olivenite.—Hydrous Copper Arsenate.

Orthorhombic; $I \wedge I = 92° 30'$. In prismatic crystals; also fibrous, and granular massive. Olive-green, and of other greenish shades, to liver and wood-brown. Streak olive-green to brown. Subtransparent to opaque. Brittle. H. = 3. G. = 4·13–4·38; fibrous, 3·9–4.

Composition. $Cu_4O_9As_2$ (or $4CuO + As_2O_5$) = Arsenic pentoxide 40·66, copper oxide 56·15, water 3·19 = 100. Fuses very easily, coloring the flame bluish green. B.B. fuses with deflagration, giving off arsenical fumes, and affords a brittle globule, which with soda yields metallic copper.

Obs. From Cornwall, the Tyrol, Siberia, Chili; Tintic Dist., Utah.

There are also the following salts of copper:

Copper Arsenates.—Euchroite is bright emerald-green; contains 33 per cent. of arsenic acid, and 48 of copper oxide; occurs in modified rhombic prisms; H. = 3·75; G. = 3·39; from Libethen, in Hungary. *Clinoclasite* (*Aphanesite*) is of a dark verdigris green inclining to blue, and also dark blue; H. = 2·5–3; G. = 4·19–4·36; contains 62·7 per cent. of copper oxide; from Cornwall. *Erinite* occurs in emerald-green mammillated coatings; H. = 4·5–5; G. = 4·04; contains 59·4 per cent. of copper oxide; from Limerick, Ireland. *Liroconite* varies

from sky-blue to verdigris-green; occurs in rhombic prisms, sometimes an inch broad; H. = 2–2·5; G. = 2·88–2 98. *Chalcophyllite* (*Copper mica*) is remarkable for its thin foliated or mica-like structure; color emerald or grass green; H. = 2; G. = 2·43–2·66; contains 58 per cent. of copper oxide; from Cornwall and Hungary. *Tyrolite* (*Copper froth*) is another arsenate of a pale apple-green and verdigris-green color, having a perfect cleavage; contains 43·9 per cent. of copper oxide; from Hungary, Siberia, the Tyrol, and Derbyshire. *Conichalcite, Cornwallite, Chlorotile, Chenevixite,* are names of other copper arsenates. These different arsenates of copper give an alliaceous odor when heated on charcoal before the blowpipe.

Mixite. A hydrous arsenate containing 13 per cent. of oxide of bismuth (Bi_2O_3), emerald to bluish green; prismatic. Joachimstahl.

Leucochalcite. A *white*, silky, hydrous copper arsenate. Spessart, Germany.

Trippkeite. Tetragonal; bluish green; copper arsenite. Copiapo, Chili.

Chalcomenite. A hydrous copper selenite, in bright blue crystals. Mendoza, S. A.

Copper Phosphates.—Pseudomalachite (*Phosphochalcite, Ehlite, Dihydrite*) In very oblique crystals, or massive and incrusting; of an emerald or blackish green color; H. = 4·5–5; G. = 4–4·4; contains 64 to 70 per cent. of copper oxide; from near Bonn, on the Rhine, and also from Hungary. *Libethenite* has a dark or olive-green color, and occurs in crystals, usually octahedral in aspect, and massive; H. = 4; G. = 3·6–3·8; contains 66·5 per cent. of oxide of copper; from Hungary and Cornwall. Other copper phosphates are *Veszelyite* (hydrous arseno-phosphate), *Tagilite, Isoclasite. Torbernite* is a copper-uranium phosphate (p. 170). These phosphates give no fumes before the blowpipe, and react for phosphoric acid.

Copper Vanadates.—Volborthite is a copper-barium-calcium vanadate from the Urals; *Mottrammite* and *Psittacinite*, copper-lead vanadates, the former from England, the latter from gold-mines in Silver Star district, Montana.

Thrombolite, an antimonate. *Stetefeldite, Partzite*, antimonite.

Rivotite. Yellowish-green copper antimonate and carbonate.

Gerhardtite. Copper nitrate in orthorhombic crystals; dark green; insoluble. United Verde Mines, Jerome, Ariz.

CARBONATES.

Malachite.—Green Copper Carbonate.

Monoclinic. Usual in incrustations, with a smooth tuberose, botryoidal, or stalactitic surface; structure finely and firmly fibrous. Also earthy.

Color light green, streak paler. Usually nearly opaque; crystals translucent. Lustre of crystals adamantine inclining to vitreous; but fibrous incrustations silky on a cross fracture. Earthy varieties dull. H. = 3·5–4. G. = 3·7–4.

Composition. $Cu_2O_4C + H_2O$ (or $2CuO + CO_2 + H_2O$)

= Carbon dioxide (or carbonic acid) 19·9, copper oxide 71·9, water 8·2 = 100. Dissolves with effervescence in nitric acid.

B.B. decrepitates and blackens, colors the flame green, and becomes partly a black scoria. With borax, fuses to a deep-green globule, and ultimately affords a bead of copper.

Diff. Readily distinguished by its copper-green color and its associations with copper ores. Resembles a siliceous ore of copper, chrysocolla, a common ore in the mines of the Mississippi Valley; but it is distinguished by its complete solution and effervescence in nitric acid. The color also is not the bluish green of chrysocolla.

Obs. Usually accompanies other ores of copper, and forms incrustations, which, when thick, have the colors banded and delicate in their shades and blending. Perfect crystals are quite rare. The mines of Siberia, at Nischne Tagilsk, have afforded great quantities of this ore. A mass, partly disclosed, measured at top 9 feet by 18; and the portion uncovered contained at least half a million pounds of pure malachite. Other noted foreign localities are Chessy, in France; Sandlodge, in Shetland; Schwatz in the Tyrol; Cornwall; the Island of Cuba; Serro do Bembe, west coast of Africa; copper mines of Australia; Chili.

Occurs in Cheshire, Ct.; Morgantown, Perkiomen, and Phœnixville, Pa.; Schuyler's Mine, and the New Brunswick copper mine, N. J.; between Newmarket and Taneytown in the Catoctin Mountains, Md.; in the Blue Ridge, Pa., near Nicholson's Gap; also in Tintic district, Utah; Calaveras Co., Cal.; Colorado; Arizona; Idaho. At Mineral Point, Wisconsin, a bluish silico-carbonate of copper occurs, which is for the most part chrysocolla, or a mixture of this mineral with the carbonate.

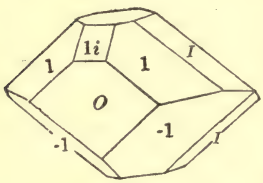
Receives a high polish and is used for tables, mantelpieces, vases; and also ear-rings, snuff-boxes, and various ornamental articles. Too soft to be much prized in jewelry. The tables, vases, and other articles made of it have great beauty.

Malachite is sometimes passed off in jewelry as turquois, though easily distinguished by its shade of color and much inferior hardness. It is a valuable ore when abundant; but it is seldom smelted alone, because the metal is liable to escape with the liberated volatile ingredient.

Alumina phosphate
H. 6

Azurite.—Blue Copper Carbonate. Blue Malachite.

Monoclinic. In modified oblique rhombic prisms, the crystals rather short and stout; lateral cleavage perfect. Also massive. Often earthy.



Color deep blue, azure-blue, Berlin-blue. Transparent to nearly opaque. Streak bluish. Lustre vitreous, almost adamantine. Brittle. H. = 3·5–4·5. G. = 3·5–3·83.

Composition. $Cu_3O_7C_2 + H_2O$ (or $3CuO + 2CO_2 + H_2O$) = Carbon dioxide 25·6, copper oxide 69·2, water 5·2. B.B. and in acids like the preceding.

Obs. Accompanies other ores of copper. Chessy, France, has afforded fine crystals; found also in Siberia; the Banat; near Redruth in Cornwall; at Phœnixville, Pa., in crystals; in Wisconsin near Mineral Point; as incrustations, and rarely as crystals, near New Brunswick, N. J.; near Nicholson's Gap, in the Blue Ridge, Pa.

When abundant, a valuable ore of copper. Makes a poor pigment, as it is liable to turn green.

Aurichalcite (*Buratite*). A hydrous copper-zinc carbonate, or a cuprous hydrozincite; pale green to sky-blue; Altai; Retzbanya; Chessy in France; Tyrol; pain; Leadhills in Scotland; Lancaster, Pa.

Silicates.

Dioptase.—Copper Silicate.

Rhombohedral; $R \wedge R = 126° 24'$. Occurs in six-sided prisms with rhombohedral terminations. Color emerald-green. Lustre vitreous. Transparent to nearly opaque. H. = 5. G. = 3·28–3·35.

Composition. CuH_2O_4Si = Silica 38·1, copper oxide 50·4, water 11·5 = 100. B.B. with soda on charcoal yields copper, and this, with its hardness, distinguishes it from the species it resembles.

Obs. From the Khirgeez Steppes of Siberia; Chili; near Clifton, Arizona.

Chrysocolla.—Hydrous Copper Silicate.

Usually as incrustations; botryoidal and massive; in thin seams and stains; no fibrous or granular structure apparent, nor any appearance of crystallization.

Color clear bluish green. Lustre of surface of incrustations smoothly shining; also earthy. Translucent to opaque. H. = 2–4. G. = 2–2·4.

Composition. $CuO_3Si + 2$ aq (or $CuO + SiO_2 + 2$ aq) = Silica 34·2, copper oxide 45·3, water 20·5 = 100.

	SIBERIAN.	NEW JERSEY.		
	Von Kobell.	Berthier.	Bowen.	Beck.
Oxide of copper	40·0	55·1	45·2	42·6
Silica	36·5	35·4	37·3	40·0
Water	20·2	28·5	17·0	16·0
Carbonic acid	2·1	—	—	—
Oxide of iron	1·0	—	—	1·4

Varies much in the proportion of its constituents, as it is not crystallized. *Pilarite* is an aluminous variety.

B.B. blackens in the inner flame, and yields water without melting. With soda on charcoal yields a globule of copper.

Diff. Distinguished from green malachite as stated under that species.

Obs. Accompanies other copper ores in Cornwall, Hungary, the Tyrol, Siberia, Thuringia, etc. Abundant in Chili at various mines; in Wisconsin and Missouri worked for copper. Formerly taken for green malachite. Occurs at the Somerville and Schuyler's mines, N. J.; at Morgantown, Pa.; Cheshire, Ct.; Utah, Colorado; California; N. S. Wales.

This ore in the pure state affords 30 per cent. of copper; but as it occurs in the rock will hardly yield one-third this amount. Still, when abundant, as it appears to be in the Mississippi Valley, it is a valuable ore.

Neocianite is a blue monoclinic mineral, supposed to be an anhydrous copper silicate. Vesuvius.

General Remarks.—The most valuable sources of copper for the arts are *native copper*, *chalcopyrite* or "yellow copper ore," *chalcocite* or "copper glance," *bornite* or "variegated copper ore," *malachite* or "green carbonate of copper," *chrysocolla* or "silicate," *cuprite* or "red oxide of copper;" and occasionally "black copper."

The principal copper regions, exclusive of the American, are as follows: The Cornwall and Devon, England, where the ore is mostly

chalcopyrite; about Mansfeld, in Prussia, having the ore distributed through a bed of red shale in the Permian (Kupferschiefer), about eighteen inches thick, making about 2½ per cent. of the bed; the Urals on their western slope, in the Permian, as in Mansfeld; also more productively on the eastern side of the Urals, at the Nischne Tagilsk and Bogoslowskoi mines, in Silurian limestone where traversed by eruptive rocks, and at the Gumeschewskoi mine, in argillaceous shale, the ore chiefly malachite and cuprite; in France, at Chessy, near Lyons, of malachite and azurite, now of little value; in Norway, at Alten, and in Sweden, at Fahlun; in Hungary, at Schemnitz, Kremnitz, Kapnik, and the Banat; in Italy, at Monte Catini; in Spain, in the province of Huelva, where is the Rio Tinto mine, which affords chalcopyrite, and also the sulphate (p. 152); in Portugal, at San Domingo, near the mouth of the Guadiana; in Algeria, Turkey, China, Japan, Cape of Good Hope; in South Australia, where are three prominent mines, the Burra, Wallaroo, and Moonta, their yield in 1875, £451,500; New South Wales, the largest mine at Cobar, 500 m. W. of Sydney.

In South America, in Chili, in the vicinity of Copiapo, and less abundantly at other places to the south; in Bolivia, also in Peru, and the Argentine Republic, but not much developed. In Cuba, but much less productive than formerly.

In Eastern North America some copper has been afforded by the Triassic of New Jersey and the Connecticut Valley, but there are no producing mines. At Ely, Vt., and Milan, N. H., veins of chalcopyrite are worked. The chief sources of copper are the veins of Northern Michigan, where the veins are connected with trap-dikes intersecting a Cambrian red sandstone, as stated on page 145. The Cliff mine was one of the earliest opened, and there the largest masses of native copper have been found. Other veins have since been opened in various parts of the region, at Eagle Harbor, Eagle River, Grand Marais, Lac La Belle, Agate Harbor, Torch Lake, on the Ontonagon, in the Porcupine Mountains, and elsewhere. In Tennessee, at the Hiwassee mines, but work suspended; in Virginia, at Tolersville; in North Carolina, at Ore Knob; in Georgia, the Tallapoosa mines; in Missouri, in Sainte Genevieve Co., from one or two levels in the Lower Silurian limestone; also north of Lakes Superior and Huron, and on Isle Royale and the Michipicoten Islands, in Lake Superior, but not now productive; in Newfoundland valuable mines at Tilt Cove and Betts Cove mines, and in the vicinity of Capelton.

In Western North America, in Arizona, there are large veins of copper north of the Gila, on the borders of New Mexico, in the Clifton, Warren, and Globe districts; in New Mexico, in the Nacimiento Mts., the Sandia Mts., east of Albuquerque, the Andreas Mts., and elsewhere; in Colorado, at the towns of Central, Black Hawk, and Nevada in Gilpin Co.; in the San Juan Mts., north of Cañon City; in Utah, in the Tintic district; in Montana, near Butte City; also in Idaho, Wyoming, and Nevada, but mostly awaiting development; in California, at Copperopolis (formerly worked); at Spenceville in Nevada Co.

The total production of copper in the United States in 1845 was 100 long tons, 12 of it from the Lake Superior region; in 1855, 3000, with 2593 from L. S.; in 1865, 8500, with 6410 from L. S.; in 1875, 18,000,

with 16,089 from L. S.; in 1880, 27,000, with 22,204 from L. S.; in 1885, 74,000, with 32,210 from L. S., 30,270 from Montana, 10,135 from Arizona and 1435 from other States. The world's production for 1880 is estimated at 153,057 tons, and for 1885 at 221,715 tons. Of the latter, Chili produced 38,500 tons; Spain and Portugal about 46,000; Germany about 15,000; Australia, 11,400; Japan, 10,000; Southern Africa, 5450; Sweden, 5000; Venezuela, 4111; England about 3000, and other countries about 9000 tons.

In 1884, the Calumet and Hecla mine, Michigan, yielded 40,473,585 pounds; the Quincy, 5,680,087; the Osceola, 4,247,630; the Franklin, 3,748,652; the Atlantic, 3,163,585; all the other L. Superior mines about 12,000,000 pounds.

The metal copper was known in the earliest periods and was used mostly alloyed with tin, forming *bronze*. The mines of Nubia and Ethiopia are believed to have produced a great part of the copper of the early Egyptians. Eubœa and Cyprus are also mentioned as affording this metal to the Greeks. It was employed for cutting instruments and weapons, as well as for utensils; and bronze chisels are at this day found at the Egyptian stone quarries, that were once employed in quarrying. This bronze (*chalkos* of the Greeks, and *æs* of the Romans) consisted of about 5 parts of copper to 1 of tin, a proportion which produces an alloy of maximum hardness. Nearly the same material was used in early times over Europe; and weapons and tools have been found consisting of copper, edged with iron, indicating the scarcity of the latter metal. Similar weapons have also been found in Britain; yet it is certain that iron and steel were well known to the Romans and later Greeks, and to some extent used for warlike weapons and cutlery. Bronze is hardened by hammering or pressure.

Copper knives, axes, chisels, spear-heads, bracelets, etc., have been found in the Indian mounds of Wisconsin, Illinois, and the neighboring States; and there is evidence that the Indians, besides using drift masses of copper, knew of the copper veins of Northern Michigan, and worked them, especially in the Ontonagon region, where their tools and excavations have been discovered.

Copper at the present day is very various in its applications in the arts. It is largely employed for utensils, for the sheathing of ships, and for coinage. Alloyed with zinc it constitutes brass, and with tin it forms bell-metal as well as bronze.

Brass consists of copper 65 per cent., zinc 35; with 53·5 per cent. of zinc the alloy is silver-white; *casting brass* of 65–72 copper, 35–28 zinc; *ormolu* or Dutch metal, of 70–85 copper, 15–25 zinc, with 0·3 of each, lead and tin; *brass for lathe-work* of 60–70 copper, 28–38 zinc, 2 lead; *Muntz metal*, for the sheathing of ships, 60 copper, 39 zinc, 1 lead; *spelter solder* for brass, copper 50, zinc 50.

Bronze for medals consists of copper 93, tin 7; for speculum metal, copper 60, tin 30, arsenic 10; for casting bronze, copper 82–83, tin 1–3, zinc 17–18; for gun-metal, copper 85–92, tin 8–15; for bell-metal, copper 65–80, tin 20–35, antimony 0–2; antique bronze, copper 67–95, tin 8–15, lead 0–1, zinc 0–15.

Lord Rosse used for the speculum of his great telescope 126 parts of copper to 57½ parts of tin. The brothers Keller, celebrated for

their *statue castings*, used a metal consisting of 91·4 per cent. of copper, 5·53 of zinc, 1·7 of tin, and 1·37 of lead. An equestrian statue of Louis XIV., 21 feet high, and weighing 53,263 French pounds, was cast by them in 1699, at a single jet.

An alloy of copper 90, and aluminium 10, is sometimes used in place of bronze.

LEAD.

Lead occurs rarely native; generally in combination with sulphur; with arsenic, tellurium, selenium, and in the condition of sulphate, carbonate, phosphate and arsenate, chromate and molybdate.

The ores of lead vary in specific gravity from 5·5–8·2. They are soft, the hardness of the species with metallic lustre not exceeding 3, and others not over 4. They are easily fusible before the blowpipe (excepting plumboresinite); and with soda on charcoal (and often alone), malleable lead may be obtained. The lead often passes off in yellow fumes, when the mineral is heated on charcoal in the outer flame, or it covers the charcoal with a yellow coating.

Native Lead.

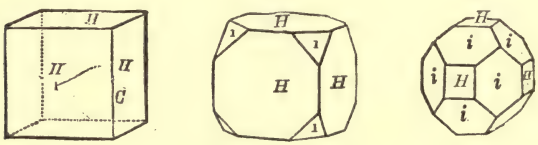
A rare mineral, occurring in thin laminæ or globules. G. = 11·35. Said to have been seen in the lava of Madeira; at Alston in Cumberland with galena; in the County of Kerry, Ireland; in an argillaceous rock at Carthagena; at Camp Creek, Montana; Jay Gould Mine, Idaho, in galena.

Sulphides, Selenides, Tellurides.

Galenite.—Galena. Lead Sulphide.

Isometric. Cleavage cubic, eminent, and very easily obtained. Also coarse or fine granular; rarely fibrous.

1. 2. 3.



Color and streak lead-gray. Lustre shining metallic. Fragile. H. = 2·5. G. = 7·25–7·35; 6·93–7·7.

Composition. PbS = Sulphur 13·4, lead 86·6 = 100.

Often contains some silver sulphide, and is then *argentiferous galena;* at times zinc sulphide is present. The ore of veins intersecting crystalline metamorphic rocks is most likely to be argentiferous. The proportion of silver varies greatly. In Europe, when it contains only 7 or 8 ounces to the ton it is worked for the silver. The galenite of the Hartz afords ·03 to ·05 per cent. of silver; the English ·02 to ·03 per cent.; that of Leadhills, Scotland, ·03 to ·06; that of Pike's Peak, Colorado, ·05 to ·06; that of Arkansas, ·03 to ·05; that of Middletown, Ct., ·15 to ·20; that of Roxbury, Ct., 1·85; that of Monroe, Ct., 3·0; while that of Missouri afforded Dr. Litton only ·0012 to ·0027 per cent. A little antimony or cadmium is sometimes present.

B.B. on charcoal, it decrepitates unless heated with caution, and fuses, giving off sulphur, coats the coal yellow, and finally yields a globule of lead.

Diff. Resembles some silver and copper ores in color, but its cubical cleavage, or granular structure when massive, will usually distinguish it. Its reactions before the blowpipe show it to be a lead ore, and a sulphide.

Obs. Occurs in granite, limestone, argillaceous and sandstone rocks, and is often associated with ores of zinc, silver, and copper. Quartz, barite, or calcite is generally the gangue of the ore; also at times fluor spar. The rich lead-mines of Derbyshire, and the northern districts of England, occur in the Subcarboniferous limestone; and the same rock contains the valuable deposits of Bleiberg, in Austria, and the neighboring deposits of Carinthia. The ore of Cornwall is in true veins intersecting slates and is argentiferous. At Freiberg in Saxony, it occupies veins in gneiss; in the Upper Hartz, and at Przibram in Bohemia, it traverses clay slate of Lower Silurian age; at Sahla, Sweden, it occurs in crystalline limestone. There are other valuable beds of galena, in France at Poullaouen and Huelgoet, Brittany, and at Villefort, Department of Lozère; in Spain in the granite and argillyte hills of Linares, in Catalonia, Granada, and elsewhere; in Savoy; in Netherlands at Vedrin, not far from Namur; in Bohemia, southwest of Prague; in Joachimstahl, where the ore is worked principally for its silver; in Siberia in the Daouria Mountains in limestone, argentiferous and worked for the silver.

Deposits of this ore occur in limestone, in the States of

Missouri, Illinois, Iowa, and Wisconsin; argillaceous iron ore, pyrite, calamine and smithsonite ("dry bone" of the miners), blende ("black-jack"), carbonate of lead or cerussite, and barite or heavy spar, are the most common associated minerals; and less abundantly chalcopyrite and malachite, ores of copper; also occasionally the lead ores, anglesite and pyromorphite; and in the Mine La Motte region, black cobalt, and linnæite, an ore of nickel.

Lead ore was first noticed in Missouri in 1700 and 1701. In 1720 the mines were rediscovered by Francis Renault and M. La Motte; and the La Motte bears still the name of the latter. Afterward the country passed into the hands of Spaniards, and during that period, in 1763, a valuable mine was opened by Francis Burton, since called *Mine à Burton*.

The lead region of Wisconsin, according to Dr. D. D. Owen, comprises 62 townships in Wisconsin, 8 in Iowa, and 10 in Illinois, being 87 miles from east to west, and 54 miles from north to south. The ore, as in Missouri, is abundant. The ore, according to Whitney, occupies cavities or chambers in the limestone instead of true veins, and in this respect it is like that of Derbyshire and Northern England.

The mines of Wisconsin and Illinois are in Lower Silurian limestone of the Trenton period, called the Galena limestone; those of Southeastern Missouri, situated chiefly in Franklin, Jefferson, Washington, St. François, St. Genevieve, and Madison counties, are in the "Third Magnesian limestone;" also Lower Silurian, but of the Calciferous or Potsdam period; those of Southwestern Missouri, situated mostly in Newtown, Jasper, Lawrence, Green, and Dade counties, and in the western part of McDonald, Barry, Stone, and Christian counties, are in the "Keokuk limestone," of the Subcarboniferous period, but partly in Webster, Taney, Christian, and Barry counties, in the Lower Silurian "magnesian limestone;" those of Central Missouri, situated in Moniteau, Cole, Miller, Morgan, and other counties, are mostly in the Lower Silurian "magnesian limestone," but partly, as in Northern Moniteau, in the Subcarboniferous. The conditions in which the ore occurs in Missouri confirms the opinion of Prof. Whitney, as to there being no true veins. Mr. Adolph Schmidt, in his account of the Missouri lead ores, says that the deposits

contain red clay, broken chert, from the chert bed, and portions of the limestone beds, along with the lead; that the barite was introduced after the lead; that some caves are filled through all their ramifications, while others are only partly filled; and he adds that the same solvent waters that made the caves and horizontal fissures or openings may have held the various minerals in solution. In Derbyshire, England, the deposits contain fossils of Permian rocks, showing that, although occurring in Subcarboniferous limestone, they were much later in origin.

In Colorado, at Leadville, there are very productive mines, which yield also gold and silver; also at the mines of Georgetown, in Clear Creek Co., and in the San Juan district; in Montana at several localities; in Idaho; in Arizona; in Nevada abundant in the Eureka district, the principal mines of which are the Richmond and Eureka; also in the Castle Dome and other districts; in Utah at several mines; in California, in Inyo Co.; in New Mexico, in the Magdalena Mountains, Socorro Co.; and in Los Cerillos district, Santa Fé Co.

Galenite also occurs much less abundantly in the region of Chocolate River and elsewhere, Lake Superior copper region; on Thunder Bay and Black Bay; at Cave-in-Rock, Ill., along with fluorite; at Rossie, in St. Lawrence Co., N. Y., in gneiss, in a vein 3 to 4 feet wide near Wurtzboro' in Sullivan Co., a large vein in millstone grit, at Ancram, in Columbia Co., Martinsburg, in Lewis Co., and Lowville; at Lubec; and of less interest at Blue Hill Bay, Birmingham and Parsonsfield, Me.; at Eaton, Bath, Tamworth, and Haverhill, N. H.; at Thetford, Vt.; at Southampton, Leverett, and Sterling, and Newburyport, Mass.; at Middletown, Ct., formerly worked as a silver-lead mine; in Wythe County, Louisa County, Va., and elsewhere; at King's Mine, Davidson Co., N. C., where the lead appears to be abundant; at Brown's Creek, and at Haysboro', near Nashville, Tenn.; at Phœnixville, Pa.; in Michipicoten and Spar Islands, Lake Superior.

The lead of commerce is obtained from this ore. It is also employed in glazing common stoneware: for this purpose it is ground to an impalpable powder and mixed in water with clay; into this liquid the earthen vessel is dipped and then baked.

Abbeville Co
Anderson Co
Greenville Co

Retzbanyite, Cosalite. Lead sulpho-bismuthide; steel-gray. Cosala and Sinalva, Mexico; Retzbanya, Hungary.

Begeerite, another sulpho-bismuthide. Baltic Lode, Col.

Bjelkite. Near Cosalite. Bjelka mine, Sweden.

Lead Selenides and Tellurides.

These various ores of lead are distinguished by the fumes B.B., and by yielding, on charcoal, ultimately, a globule of lead.

Clausthalite, Lead selenide; lead-gray; fracture granular, occasionally foliated; H. = 2·5–3; G. = 7·6–8·8; B.B. on charcoal a horse-radish odor (that of selenium). The Hartz. A *lead and copper selenide* (*Zorgite*) has G. = 7–7·5. A *lead and mercury selenide* (*Lehrbachite*) occurs in foliated grains or masses of a lead gray to bluish and iron-black color.

Altaite, or *Lead telluride.* Tin white; cleavable; H. = 3–3·5; G. = 8 16. The Altai.

Nagyagite, Foliated tellurium. Remarkable for being foliated like graphite; color and streak blackish lead gray; H. = 1–1·5; G. = 7·085; contains Tellurium 32·2, lead 54·0, gold 9·0, with often silver, copper, and some sulphur. Transylvania.

Sulpharsenites, Sulphantimonites, and Sulpho-bismuthites.

These species include, of (A) Sulpharsenites: *Freieslebenite* (p. 133), *Sartorite, Dufrenoysite, Guitermanite;* of (B) Sulphantimonites: *Jamesonite, Boulangerite, Zinkenite, Plagionite, Semseyite, Brongniardite* (p. 133), *Meneghinite, Geocronite, Dürfeldtite, Plumbostannite* (containing 16 p. c. tin); of (C) Sulpho-bismuthites: *Kobellite, Aikinite, Alaskaite, Galenobismutite.* Of these only *Jamesonite, Boulangerite, Zinkenite, Aikinite, Kobellite* occur often in fibrous forms.

A. *Dufrenoysite.* Orthorhombic; blackish lead-gray. Binnen.

Jamesonite. Orthorhombic; usually fibrous (*Feather ore*), also massive; lead-gray; G. = 5·5–5·7. Cornwall; Hungary; Siberia; Tuscany; Arkansas.

Guitermanite. Bluish gray, slightly metallic; G. = 5·94; about 62 p. c. of lead. The Zuñi mine, San Juan Co., Col.

B. *Boulangerite.* Plumose and massive; bluish lead-gray; G. = 5·75–6. Molières, France; Wolfsberg, Hartz; Tuscany.

Zinkenite. Orthorhombic; color and streak steel-gray; G. = 5·30–to 5·35. Wolfsberg, Hartz; Brobdignag mine, San Juan Co., Col.

Plagionite. Monoclinic; blackish lead-gray; G. = 5·4. Wolfsberg.

Meneghinite. Monoclinic; G. = 6·4. Bottino, Tuscany; Marble Lake, Ontario, Canada.

Aikinite (*Needle ore*). Acicular crystals and massive; contains copper with the lead. Beresof, Ural; gold region, Georgia.

C. *Kobellite.* Resembles stibnite. Contains 40 p. c. of lead and 27 of bismuth. Sweden; near Leadville, on Printerboy Hill, Col. (affording about 44 p. c. of lead and 33 of bismuth).

Galenobismutite. Contains 27 p. c. of lead to 54 of bismuth. Sweden.

Alaskaite. Massive, whitish lead-gray. Contains lead and silver, with 45 to 57 p. c. of bismuth. Alaska mine, San Miguel Co. (San Juan region), Col.

Oxides.

Minium.—Oxide of Lead.

Pulverulent. Color bright red, mixed with yellow. G. = 4·6. *Composition*, Pb_3O_4. B.B. affords globules of lead in the reduction flame.

Obs. Occurs at various mines, usually associated with galena, and is found at Austin's Mines, Wythe Co., Va.; with cerussite.

Uses. Minium is the *red lead* of commerce; but for the arts it is artificially prepared.

Plumbic ochre. Lead protoxide; color yellow.

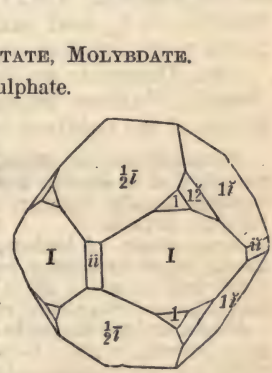
Mendipite. Orthorhombic; white, yellowish or reddish; nearly opaque; pearly; G. = 7–7·1; $PbCl_2 + PbO$ = Chloride of lead 38·4, lead oxide 61·6. Mendip Hills. *Matlockite* is Pb_2OCl_2.

Cotunnite. Chloride of lead, $PbCl_2$; acicular crystals; white; contains 74·5 per cent. of lead. Vesusius.

Plumbogummite. In globular forms; yellowish or reddish-brown; lustre somewhat like gum arabic; H. = 4–4 5; G. = 6·3–6·4; also a variety 4–4·9; consists of lead, alumina, and water. Huelgoet in Brittany; lead-mine in Beaujeu; the Missouri mines, with black cobalt; Canton mine, Ga.

Sulphate, Chromates, Tungstate, Molybdate.

Anglesite.—Lead Sulphate.



Orthorhombic; $I \wedge I = 103° 43\frac{1}{2}'$. In rhombic prisms and other forms. Lateral cleavage. Also massive; lamellar or granular.

Color white or slighly gray or green. Lustre adamantine; sometimes a little resinous or vitreous. Transparent to nearly opaque. Brittle. H. = 2·75–3. G. = 6·35–6·4.

Composition. PbO,S (or $PbO + SO_3$), affording about 73 per cent. of lead oxide. B.B. fuses in the flame of a candle; on charcoal, with soda, yields lead.

Diff. Distinguished by its specific gravity, and by yielding lead. B.B differs from lead carbonate in lustre, and in not dissolving with effervescence in acid.

Obs. Usually associated with galenite, and results from its decomposition. Occurs in fine crystals at Leadhills and Wanlockhead, Great Britain, and also at other foreign lead-mines. In the United States, at the lead-mines of Missouri and Wisconsin; in fine crystallizations at Phœnixville, Pa.; sparingly at the Walton gold-mine, Louisa Co., Va.; at Southampton, Mass.; in Arizona, in many mines; Cerro Gordo, Cal.; Clear Creek and Lake Cos., Col.; Nevada; Utah.

Linarite. Hydrous lead-copper sulphate; deep azure-blue; one perfect cleavage; G. = 5·3–5·45. Leadhills, Red Gill, Keswick; Schneeberg; Urals.

Lead Sulphato-carbonates, Anhydrous.—Caledonite. Color verdigris to bluish green. Leadhills, etc.; Mine la Motte, Mo.

Leadhillite (*Maxite*). Orthorhombic; white, yellow, gray; G. = 6·25–6·45. Leadhills, etc. Susannite; the same, but rhombohedral.

Lanarkite. Monoclinic; white, yellowish, gray, greenish; G. = 6·3–7. Leadhills, Lanarkshire, Scotland; Siberia; Hartz; Tyrol.

Crocoite.—Crocoisite. Lead Chromate.

Monoclinic. In oblique rhombic prisms, massive, of a bright red color and translucent. Streak orange-yellow. H. = 2·5–3. G. = 5·9–6·1.

Composition. PbO_4Cr (or $PbO + CrO_3$) = Chromium trioxide 31·1, lead oxide 68·9. Blackens and fuses, and forms a shining slag containing globules of lead.

Obs. Occurs in gneiss at Beresof in Siberia, and also in Brazil; Vulture region, Arizona. This is the *chrome yellow* of the painters.

Phœnicochroite (or *Melanochroite*). Another lead chromate; contains 23·0 of chromium trioxide, and is dark red; streak brick-red; crystals usually tabular and reticulately arranged; G. = 5·75. Siberia; Arizona.

Vauquelinite. A lead-copper chromate; very dark green or pearly black; usual in minute irregularly aggregated crystals; also reniform and massive; H. = 2·5–3; G. = 5·5–5·8. Siberia; Brazil; lead-mine near Sing Sing, mammillary; Arizona.

Stolzite, or *Lead tungstate.* In square octahedrons or prisms; green, gray, brown, or red. Lustre resinous; H. = 2·5–3; G. = 7·9–8·1; contains 51 of tungstic acid and 49 of lead. Zinnwald.

Wulfenite, or *Lead molybdate.* In tetragonal crystals, octahedral and tabular; also massive; yellow; lustre resinous; contains molybdenum trioxide 34·25, lead protoxide 64·42. Bleiberg and elsewhere in Carinthia; Hungary; sparingly at Southampton, Mass.; in fine crystals at Phœnixville, Pa.; at Tecoma and Eureka, Nev.; Silver and other districts, Arizona; in Los Cerillos, N. Mexico.

PHOSPHATES, ARSENATES, VANADATES, ANTIMONATES.

Pyromorphite.—Lead Phosphate.

Hexagonal. In hexagonal prisms; often in crusts made of crystals. Also in globules or reniform, with a radiated structure.

Color bright green to brown; sometimes fine orange-yellow, owing to an intermixture with chromate of lead. Streak white or nearly so. Lustre more or less resinous. Nearly transparent to subtranslucent. Brittle. H. = 3·5–4. G. = 6·8–7·1; impure 5–6.

Composition. $Pb_3O_8P_2 + \frac{1}{3}PbCl_2$ (or $3\,PbO + P_2O_5 + \frac{1}{3}PbCl_2$) = Phosphorus pentoxide 15·71, lead oxide 82·27, chlorine 2·62 = 100·60. B.B. fuses easily in the forceps, coloring the flame bluish green. On charcoal fuses, and on cooling the globule becomes angular; coats the coal white from the chloride, and, nearer the assay, yellow from lead oxide. Soluble in nitric acid.

Diff. Has some resemblance to beryl and apatite, but is quite different in its action before the blowpipe, and much higher in specific gravity.

Obs. Leadhills, Wanlockhead, and some lead-mines of Europe are foreign localities. In the U. States, well crystallized at King's Mine, in Davidson Co., N. C.; other localities are the Perkiomen and Phœnixville mines, Pa.; Lubec lead-mines, Me.; Lenox, N. Y.; formerly, a mile south of Sing Sing, N. Y.; the Southampton lead-mine, Mass.; sparingly in Arizona, Mexico, New Mexico, and Nevada, where the phosphate is replaced by vanadate.

The name *pyromorphite* is from the Greek *pur*, fire, and *morphe*, form, alluding to its crystallizing on cooling from fusion before the blowpipe.

Mimetite. A lead arsenate, resembling pyromorphite in crystallization, but giving a garlic odor on charcoal B.B.; pale yellow, passing into brown; H. = 3·75–3·5; G. = 6·41; composition, $Pb_3O_8As_2 + \frac{1}{3}PbCl_2$ = Arsenic pentoxide 23·20, lead oxide 74·96, chlorine 2·30 = 100·55. Cornwall and elsewhere; Phœnixville, Pa.; Vulture distr., Arizona. *Endlichite* is a vanadiferous mimetite from New Mexico.

Hedyphane is a variety of mimetite containing much lime; amorphous; whitish; lustre adamantine; H. = 3·5–4; G. = 5·4–5·5. Longban, Sweden.

Karyinite. A lead arsenate containing manganese and calcium. Norway.

Ecdemite. Lead chloro-arsenate; yellow to green. Sweden.

Achrematite. Lead arsenate and molybdate; color yellow to red. A doubtful species. Mexico.

Phosphochromite. A chromate and phosphate. Beresof.

Vanadinite. A lead vanadate. Hexagonal; in prisms like pyromorphite, and also in implanted globules; yellow to reddish brown and red; H. = 2·75–3; G. = 69–7·23. Zimapan, Mexico; in the silver districts of Arizona in red and orange crystals; Los Cerillos, N. Mexico. Wanlockhead in Dumfriesshire.

Descloizite. Lead vanadate; orthorhombic; black, brown, olive-green. Cordoba; New Mexico; Arizona; Carinthia.

Brackebuschite. A hydrous lead vanadate. Cordoba.

Dechenite. A lead-silver vanadate. Dahn and Freiberg.

Mottrammite. Lead-copper vanadate; black. Mottram, St. Andrews, England.

Eusynchite. Lead-copper vanadate; olive-green, blackish. Laurium, Greece.

Psittacinite. Lead-copper vanadate; green to olive-green. Montana.

Tritochorite. Lead-copper-zinc vanadate; S. America or Mexico.

Monimolite. A yellow lead antimonate.

Nadorite. A yellow lead chlor-antimonate.

Arequipite. Lead silico-antimonate; wax-like yellow. Peru.

Coronguite. A doubtful lead-silver antimonate.

Bindheimite. A hydrous lead antimonate.

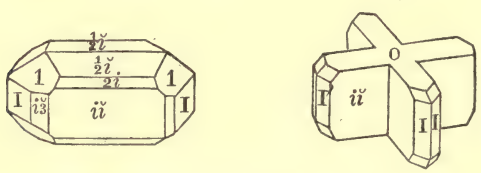
Molybdomenite. Lead-selenite. Cacheuta, S. A.

Carbonates, Silicates.

Cerussite.—White Lead Ore. Lead Carbonate.

Orthorhombic; $I \wedge I = 117° 13'$. In modified right rhombic prisms; often in compound crystals, two or three cross-

1. 2.



ing one another as in Fig. 2. Also in six-sided prisms like aragonite. Also massive; rarely fibrous.

Color white, grayish, light or dark. Lustre adamantine. Brittle. H. = 3–3·5. G. = 6·46–6·48.

Composition. PbO_3C (or $PbO + CO_2$) = Carbon dioxide 16·5, lead oxide 83·5 = 100. B.B. decrepitates, fuses, and with care on charcoal affords a globule of lead. Effervesces in dilute nitric acid.

Diff. Distinguished by its specific gravity and yielding lead when heated. From anglesite it differs in giving lead *alone* on charcoal B.B., as well as by its solution and effervescence with nitric acid, and its less glassy lustre.

Obs. Associated usually with galena. Finely crystallized at Leadhills, Wanlockhead, and Cornwall; also Linares, Spain, and other lead-mines in Europe.

In the U. S., at Austin's Mines, Wythe Co., Va.; at King's Mine, in Davidson Co., N. C.; at the latter place it has been worked for lead, and it is associated with native silver and pyromorphite; Perkiomen and Phœnixville, Pa.; at "Vallée's Diggings," Jefferson Co., Mo., and other mines in that State; at Brigham's Mine, near the Blue Mounds, Wis., partly in stalactites; at "Deep Diggings," in crystals, and at other places, both massive and in fine crystallizations; in Colorado and many Western mining regions with other lead ores.

When abundant, this ore is wrought for lead. Large quantities occur about the mines of the Mississippi Valley. It was formerly buried up in the rubbish as useless, but it has since been collected and smelted. It is a rich ore, affording in the pure state 75 per cent. of lead.

The "white lead" of commerce, extensively used as a paint; but the material so used is artificially made.

Phosgenite, or *Corneous Lead.* A lead chloro-carbonate, occurring in whitish adamantine crystals. H. = 2·75–4. G. = 6–6·3. Composition, $PbO_3C + PbCl_2$. Derbyshire and Germany.

Hydrocerussite. Hydrous lead carbonate, on native lead. From Sweden.

Ganomalite. A white lead-manganese silicate, affording 34·89 per cent. of lead oxide. Sweden. *Hyalotecite* is a lead-barium-lime silicate. *Melanotecite* is a lead-iron silicate. *Kentrolite* is a lead-manganese silicate; G. = 6·19.

General Remarks.—The lead of commerce is derived almost wholly from the sulphide of lead or galenite, the localities of which have already been mentioned; yet in some mining regions, the carbonate and sulphate are also abundant.

The lead-mines of the Central United States afforded in 1826, 1770 tons; in 1842, 24,000 short tons; in 1872, 25,880; 1875, 60,000; 1877, 82,000; 1880, 98,000; 1884, 140,000 short tons.

In 1884, Nevada produced 4000 tons; Utah, 28,000; Colorado, 63,165; Montana, 7000; Idaho, 7500; N. Mexico, 6000; Arizona, 2700; California, 1000; the States on the Mississippi, 19,676; Virginia, 256. Great Britain produced in 1874 about 59,000 long tons; in 1883, 39,160. In 1883, Germany produced 96,400 tons; Spain, 129,000 tons; France, 8000 tons; Italy, 9000 tons; Austria, 11,320 tons.

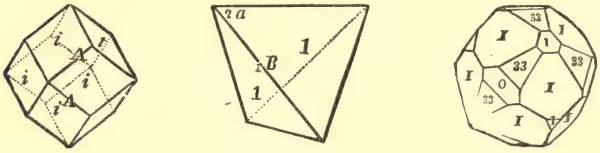
Spartanburg C

ZINC.

Zinc occurs in combination with sulphur and oxygen; and also in the condition of silicate, carbonate, sulphate, and arsenate. It is also a constituent of one variety of the species spinel. The chief sources of the metal are smithsonite or the carbonate; willemite and calamine, or silicates; zincite, or the oxide; sphalerite (blende), or the sulphide; and franklinite. Native zinc has been reported from Northern Alabama.

Sphalerite.—Blende. Zinc Sulphide. Black Jack.

Isometric. In dodecahedrons, octahedrons, and other allied forms, with a perfect dodecahedral cleavage. Also massive; sometimes fibrous. Color wax-yellow, brownish yellow to black, sometimes green, red, and white; streak



white to reddish brown. Lustre resinous or waxy, and brilliant on a cleavage face; sometimes submetallic. Transparent to subtranslucent. Brittle. H. = 3·5–4. G. = 3·9–4·2. Some specimens become electric with friction, and give off a yellow light when rubbed with a feather.

Composition. ZnS = Sulphur 33, zinc 67 = 100. Contains frequently iron sulphide when dark-colored; often also 1 or 2 per cent. of cadmium sulphide, especially the red variety; also sometimes indium and gallium. Nearly infusible alone and with borax. Dissolves in nitric acid, emitting sulphuretted hydrogen. Strongly heated on charcoal yields fumes of zinc.

Diff. This ore is characterized by its lustre, cleavage, and its being nearly infusible. Some dark varieties look a little like tin ore, but their cleavage and inferior hardness distinguish them; and some clear red crystals, which resem-

ble garnet, are distinguished by the same characters and also by their very difficult fusibility.

Obs. Occurs in rocks of all ages, associated generally with ores of lead, and often also with copper, iron, tin, and silver ores. The lead-mines of Missouri and Wisconsin afford this ore abundantly. Other localities are, at Lubec, Bingham, Dexter, Parsonsfield, Me.; at Eaton, Warren, Haverhill, Shelburne, N. H.; at Hatfield, Vt.; in Brookfield, Berlin, Roxbury, and Monroe, Ct.; at Ancram lead-mine, the Wurtzboro' lead vein, at Lockport, Root, 2 miles southeast of Spraker's Basin, in Fowler, at Clinton, N. Y.; at Franklin, N. J., colorless (*Cleiophane*); at the Perkiomen lead mine, Pa.; and a compact variety abundant at Friedensville, Saucon Valley, Pa.; with calamine in lower Silurian limestone, at Austin's lead mine, Wythe Co., Va.; near Powell's River, and at Haysboro', Tenn.; at Prince's Mine, Spar Island, Lake Superior, with ores of silver; in Beauce Co., Canada, where it is slightly auriferous; also at various mines in Colorado, Arizona, Utah, Montana, New Mexico, Idaho, California; in fine crystals at Joplin, Mo.

A useful ore of zinc, though more difficult of reduction than calamine. By its decomposition (like that of pyrite) it affords sulphate of zinc or white vitriol.

Wurtzite. Zinc sulphide in hexagonal crystals. From Bolivia; Butte Mine, Montana. *Erythrozincite* is supposed to be a manganesian variety of wurtzite.

Huascolite is a zinc-lead sulphide. *Youngite* is probably a mixture.

Zincite.—Red Zinc Ore. Zinc Oxide.

Hexagonal. Usually in foliated masses, or in disseminated grains; cleavage eminent, nearly like that of mica; but the laminæ brittle, and not so easily separable.

Color deep or bright red, by transmitted light deep yellow; streak orange-yellow. Lustre brilliant, subadamantine. Translucent or subtranslucent. H. = 4–4·5. G. = 5·68–5·74.

Composition. ZnO = Oxygen 19·7, zinc 80·3 = 100. B.B. infusible alone, but yields a yellow transparent glass with borax; on charcoal, a coating of zinc oxide. Dissolves in nitric acid without effervescence.

Diff. Distinguished by its eminent cleavage, infusibility, and also by its mineral associations.

Obs. Occurs with franklinite at Mine Hill and Sterling Hill, Sussex Co., N. J.

A good ore of zinc, and easily reduced.

Voltzite. Sulphur, oxygen and zinc, $4ZnS + ZnO$; in implanted globules; dirty rose-red; pearly on a cleavage surface. France; near Joachimstahl.

Hydrofranklinite. Isometric octahedrons; iron black; supposed to be hydrous oxide of zinc and iron. Sterling Hill, N. J.

Goslarite.—Zinc Sulphate. White Vitriol.

Orthohombic; $I \wedge I = 90° 42'$. Cleavage perfect in one direction.

Color white. Lustre vitreous. Easily soluble; taste astringent, metallic, and nauseous. Brittle. H. = 2–2·5. G. = 2·036; artificial, 1·95–1·96.

Composition. $ZnO,S + 7$ aq. (or $ZnO + SO_3 + 7$ aq.) = Zinc oxide 28·2, sulphur trioxide 27·9, water 43·9 = 100. B.B. gives off fumes of zinc on charcoal, which cover the coal.

Obs. Results from the decomposition of blende. Occurs in the Hartz; Hungary; Sweden; at Holywell in Wales.

Extensively employed in medicine and dyeing. Prepared to a large extent from blende by decomposition, though this affords, owing to its impurities, an impure sulphate. Also obtained by direct combination of zinc with sulphuric acid.

White Vitriol, as the term is used in the arts, is one form of sulphate of zinc, made by melting the crystallized sulphate, and agitating till it cools and presents an appearance like loaf sugar.

Zinc-aluminite. Hydrous zinc-aluminum sulphate; white. Laurium, Greece.

Hopeite. In orthorhombic crystals; grayish white; supposed to be a hydrous zinc-phosphate. Altenberg zinc mines.

Köttigite. Hydrous zinc-cobalt arsenate; reddish (owing to presence of cobalt). Schneeberg.

Adamite. Hydrous zinc-arsenate; honey-yellow to violet. Chili.

Smithsonite.—Zinc Carbonate.

Rhombohedral; $R \wedge R = 107° 40'$. Cleavage R perfect. Massive or incrusting; reniform and stalactitic.

Color impure white, sometimes green or brown; streak

uncolored. Lustre vitreous or pearly. Subtransparent to translucent. Brittle. H. = 5. G. = 4·3–4·45.

Composition. ZnO_3C (or $ZnO + CO_2$) = Carbon dioxide 35·2, zinc oxide 64·8 *four-fifths* of which is pure zinc) = 100. Often contains some cadmium. B.B. infusible alone, but carbonic acid and oxide of zinc are finally vaporized. Effervesces in nitric acid. Negatively electric by friction.

Diff. The effervescence with acids distinguishes this mineral from the following species; and the hardness, difficult fusibility, and the zinc fumes before the blowpipe, from the carbonate of lead or other carbonates. Besides, the crystals over a drusy surface terminate usually in sharp three-sided pyramids.

Obs. Occurs commonly with galena or blende, and usually in calcareous rocks. Found in Siberia, Hungary, Silesia; at Bleiberg in Carinthia; near Aix-la-Chapelle in the Lower Rhine, and largely in Derbyshire and elsewhere in England. In the U. States, abundant at Joplin Creek, Mine-la-Motte, Mo., and Vallée's Diggings; at lead "diggings" in Iowa and Wisconsin; in Eastern Kansas, near the Joplin Mines; also in Claiborne Co., Tenn.; sparingly at Hamburg, near Franklin Furnace, Sussex Co., N. J.; Perkiomen lead mine, Pa.

Hydrozincite (*Zinc Bloom*). Hydrous zinc carbonate, $ZnO_3C + 2ZnO_2H$, of a whitish color, with G. = 3·58–3·8.

Aurichalcite. Hydrous zinc-copper carbonate; in drusy incrustations of acicular crystals; pale verdigris-green to sky-blue. Siberia, Hungary, England, France, Tyrol, Spain; Lancaster, Pa.

Buratite. A lime aurichalcite.

Willemite.—Zinc Silicate. Troostite.

Rhombohedral; $R \wedge R = 116° 1'$. In hexagonal prisms; also massive.

Color whitish, greenish yellow, apple-green, flesh-red, yellowish brown. Streak uncolored. Transparent to opaque. Brittle. H. = 5·5. G. = 3·89–4·18.

Composition. Zn_2O_4Si (or $2ZnO + SiO_2$) = Silica 27·1, zinc oxide 72·9 = 100. B.B. fuses with difficulty to a white enamel; on charcoal, and most easily on adding soda, yields a coating which is yellow while hot, and white on cooling, and which, moistened with cobalt solution and treated in O.F., is colored bright green. Gelatinizes with hydrochloric acid.

Obs. From Moresnet, between Liège and Aix-la-Chapelle; Raibel in Carinthia; Greenland. Abundant at Franklin and Sterling, Sussex Co., N. J., mixed with zincite, and used as an ore of zinc; also in prismatic crystals that occasionally are six inches long.

Calamine.—Hydrous Zinc Silicate. Galmei.

Orthorhombic; $I \wedge I = 104° 13'$. In rhombic prisms, the opposite extremities with unlike planes. Cleavage perfect parallel to *I*. Also massive and incrusting, mammillated or stalactitic.

Color whitish or white, sometimes bluish, greenish, or brownish. Streak uncolored. Transparent to translucent. Lustre vitreous or subpearly. Brittle. H. = 4·5–5. G. = 3·16–3·9; 3·45–3·49. Altenberg. Pyro-electric.

Composition. $H_2Zn_2O_5Si$ = Silica 25·0, zinc oxide 67·5, water 7·5 = 100.

B.B. alone almost infusible. Forms a clear glass with borax. Dissolves in heated sulphuric acid; the solution gelatinizes on cooling.

Diff. Differs from calcite and aragonite by its action with acids; from a salt of lead, or any zeolite, by its infusibility; from chalcedony by its inferior hardness, and its gelatinizing with heated sulphuric acid; from smithsonite by not effervescing with acids, and by the rectangular aspect of its crystals over a drusy surface.

Obs. Occurs with galenite. In the United States it is found at Joplin Creek, Granby Dist., Mine La Motte, and Vallée's Diggings, Mo.; Perkiomen and Phœnixville lead mines; at Friedensville in Saucon Valley, two miles from Bethlehem, Pa.; abundantly at Austin's Mines, Wythe Co., Va. Valuable as an ore of zinc.

Franklinite, an ore of iron, containing manganese and zinc; see page .

General Remarks.—The metal zinc (*spelter* of commerce) is supposed to have been unknown in the metallic state to the Greeks and Romans. It has long been worked in China, and was formerly imported in large quantities by the East India Company.

The principal mining regions of zinc in the world are in Upper Silesia, at Tarnowitz and elsewhere; in Poland; in Carinthia, at Raibel and Bleiberg; in Netherlands at Limberg; at Altenberg, near Aix-la-Chapelle in the Prussian province of the Lower Rhine; at Vieille Montagne in the Liège district, Belgium; in England, in Derbyshire, Alstonmoor, Mendip Hills, etc.; in the Altai, in Russia;

besides others in Italy, Greece, Sweden, and China. In the U. States, smithsonite and calamine occur with the lead ore of Missouri in large quantities. They were formerly considered worthless and thrown aside, under the name of "dry bone." In Tennessee, Claiborne Co., there are workable mines. Calamine occurs at Friedensville, Pa., along with massive blende: it is not now worked. The zincite, willemite, and franklinite of Franklin, N. J., are together worked as a zinc ore, and both zinc and zinc oxide are produced. Blende is sufficiently abundant to be worked at the Wurtzboro' lead mine, Sullivan Co., New York, at Eaton and Warren, in N. H; at Lubec, Me.; at Austin's Mine, Wythe Co., Va.; at some of the Missouri lead mines.

The amount of zinc produced in 1885, in Europe, was, for Belgium and the Rhine, 129,734 long tons; Silesia, 79,623; Poland, 5,000; Austria, 2,928; France and Spain, 15,000; Great Britain, 23,100; United States, 34,000; making in all about 290,000 long tons. In 1884 Illinois produced about 16,000 tons; Kansas, over 7000; Missouri, nearly 5000; and the Eastern and Southern States, 7050. Market price per pound, 4 to 4·65 cents.

Zinc is a brittle metal, but admits of being rolled into sheets when heated to about 212° F. In sheets it is extensively used for roofing and other purposes, it being of more difficult corrosion, much harder, and also very much lighter than lead. It is also employed largely for coating (that is, making what is called *galvanized*) iron. Its alloys with copper (page 159) are of great importance.

The white oxide of zinc is much used for white paint, in place of white lead; and also in making a glass for optical purposes.

An impure oxide of zinc, called *cadmia*, often collects in large quantities in the flues of iron and other furnaces, derived from ores of zinc mixed with the ores undergoing reduction. A mass weighing 600 pounds was taken from a furnace at Bennington, Vt. It has been observed in the Salisbury iron furnace, and at Ancram, in New Jersey, where it was formerly called *Ancramite*.

CADMIUM.

Only two ores of this metal are known; but it exists with zinc in sphalerite, smithsonite and calamine. The cadmiferous sphalerite is called *Przibramite*. The metal cadmium (discovered by Stromeyer in 1818) is white like tin, and is so soft that it leaves a trace upon paper. It fuses at 442° F.

Greenockite. In hexagonal prisms; light-yellow; lustrous and nearly transparent; H. = 3–3·5; G. = 4·8–5. Bishopton, Scotland; Bohemia, on blende; Friedensville, Lehigh Co., Pa.

Eggonite. In translucent orthorhombic crystals; light grayish-brown; lustre subadamantine; H. = 4-5; B.B. infusible; supposed to be a silicate of cadmium. On calamine at Altenberg.

TIN.

Tin has been reported as occurring native in the gold washings of the Ural, and in Bolivia. There are two ores, a sulphide and an oxide. It is also contained in some ores of niobium, tantalum, and tungsten.

Stannite.—Tin Pyrites. Sulphuret of Tin. Tin Sulphide.

Commonly massive, or in grains. Color steel-gray to iron-black; streak blackish. Brittle. H. = 4. G. = 4·3–4·6.

Composition. Sulphur 30, tin 27, copper 30, iron 13 = 100.

Obs. From Cornwall, where it is often called *bell-metal ore*, from its frequent bronze-like appearance; also from Ireland and the Erzgebirge.

Cassiterite.—Tin Ore. Tin Oxide.

Tetragonal. In square prisms and octahedrons; often in twins; $1 \wedge 1 = 121° 40'$; $1i \wedge 1i$ (over the summit) 112° 10′ (over a terminal edge) 133° 31′. Cleavage indistinct. Also massive, and in grains.

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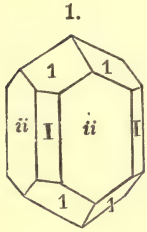

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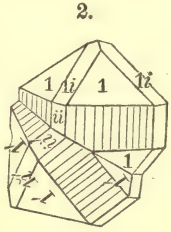


Color brown, black yellow; lustre of crystals high adamantine. Streak pale gray to brownish. Nearly transparent to opaque. H. = 6–7. G. of light-colored, 6·4–6·85; of dark, 6·8–7·02.

Composition. SnO_2 = Oxygen 21·33, tin 78·67; often contains a little iron, and sometimes tantalum. B.B. alone infusible. On charcoal with soda, a globule of tin.

Stream tin is the gravel-like ore found in débris in low grounds. *Wood tin* occurs in botryoidal and reniform shapes with a concentric and radiated structure; and *toad's-eye tin* is the same on a small scale.

Diff. Has some resemblance to a dark garnet, to black zinc blende, and to some varieties of tourmaline. Distinguished by its infusibility, and its yielding tin before the

blowpipe on charcoal with soda. Differs from blende also in its superior hardness.

Obs. Tin ore occurs in veins in granite, a quartzose gneiss, and mica schist, associated often with wolfram, pyrite, topaz, tourmaline, mica or talc, and albite. Cornwall is one of its most productive localities; also worked in Saxony, at Altenberg, Geyer, Ehrenfriedersdorf and Zinnwald; in Austria. at Schlackenwald and other places; in Malacca, Pegu, China, and especially the Island of Banca in the East Indies; in Queensland and Northern New South Wales, Australia, in large quantities; in Greenland. Occurs also in Galicia, Spain; at Dalecarlia in Sweden; in Russia; in Mexico at Durango; and Bolivia. In the United States found sparingly at Chesterfield and Goshen, Mass.; at Winslow, Me.; Lyme and Jackson, N. H.; in the eastern corner of Rockbridge Co., Va.; Ashland, Clay Co., Ala.; valuable veins in the Black Hills, Dakota, in the Harney range; in the Temescal Range, and at San Diego, Cal.; on Jordan R., Idaho; in Montana, near Helena; Nigger Hill, Wyoming.

General Remarks.—The principal tin mines now worked are those of Cornwall, Banca, Malacca, and Australia.

The Cornwall mines were worked long before the Christian era. Herodotus, 450 years before Christ, is believed to allude to the tin islands of Britain under the cabalistic name *Cassiterides*, derived from the Greek *kassiteros*, signifying *tin*. The Phœnicians are allowed to have traded with Cornubia (as Cornwall was called, it is supposed from the horn-like shape of this extremity of England). The Greeks residing at Marseilles were the next to visit Cornwall or the isles adjacent, to purchase tin; and after them came the Romans, whose merchants were long foiled in their attempts to discover the tin market of their predecessors.

Camden says: "It is plain that the ancient Britons dealt in tin mines from the testimony of Diodorus Siculus, who lived in the reign of Augustus, and Timaus, the historian in Pliny, who tells us that the Britons fetched tin out of the Isle of Icta (the Isle of Wight), in their little wicker boats covered with leather. The import of the passage in Diodorus is that the Britons who lived in those parts dug tin out of a rocky sort of ground, and carried it in carts at low water to certain neighboring islands; and that from thence the merchants first transported it to Gaul, and afterwards on horseback in thirty days to the springs of Eridanus, or the city of Narbona, as to a common mart. Æthicus too, another ancient writer, intimates the same thing, and adds that he had himself given directions to the workmen." In the opinion of the learned author of the Britannica here quoted, and others who have followed him, the Saxons seem not to have meddled with the mines, or, according to tradition, to have employed the Saracens;

for the inhabitants of Cornwall to this day call a mine that is given over working *Attal-Sarasin*, that is, the leavings of the Saracens.

The Cornwall veins, or *lodes*, mostly run east and west, with a dip —*hade*, in the provincial dialect—varying from north to south; yet they are very irregular, sometimes crossing each other, and sometimes a promising vein abruptly narrows or disappears; or again they spread out into a kind of bed or *floor*. The veins are considered worth working when but three inches wide. The gangue is mostly quartz, with some chlorite. Much of the tin is also obtained from beds of loose stones or gravel (called *shodes*), and courses of such gravel or tin débris are called *streams*, whence the name *stream tin*. The production of tin in Great Britain in 1883 was 9307 tons, valued at £735,189. Germany yields now not over 100 tons annually; and Austria, Italy, Spain, Russia, each less than this.

The Australian mines are mainly in the New England district of Northern New South Wales, and the adjoining part of Queensland, having an area of 8500 sq. m.; a large part of the ore goes north through Queensland. The value of the tin exported in 1875 from Queensland was £103,740; in 1881, £2,168,790; in 1882, £560,590. New South Wales produced, in 1875, £561,311, corresponding to 6058 tons of tin in ingots, besides 2022 tons of ore; in 1883 the amount was nearly 9000 tons. Tasmania produced in 1881 tin to the value of £375,775. Banca and Malacca, in 1882, produced over 15,000 tons.

Tin is used in castings, and also for coating other metals, especially iron and copper. Copper vessels thus coated were in use among the Romans, though not common. Pliny says that the tinned articles could scarcely be distinguished from silver, and his use of the words *incoquere* and *incoctilia* seems to imply, as a writer states, that the process was the same as for the iron wares of the present day, by *immersing the vessels in melted tin*. Its alloys with copper are mentioned on page 159. It is also used for coating copper.

Tin is also used extensively as tinfoil; but most of the modern tinfoil consists, beneath the surface, of lead, and is made by rolling out plates of lead coated with tin, an invention of Mr. J. J. Crookes. With quicksilver it is used to cover glass in the manufacture of mirrors. Tin oxide (dioxide), obtained by chemical processes, is employed, on account of its hardness, in making a paste (called "putty of tin") for polishing hard stones, for sharpening fine cutting instruments, and also to some extent in the preparation of enamels. The *chlorides* of tin are important in the precipitation of many colors as lakes, and in fixing and changing colors in dyeing and calico printing. The bisulphide has a golden lustre, and was termed *aurum musivum*, or *mosaic gold*, by the alchemists. It is much used for ornamental painting, for paper-hangings and other purposes, under the name of bronze powder.

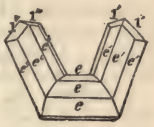
TITANIUM.

Titanium occurs in nature combined with oxygen, forming titanium dioxide or titanic acid, and also in oxygen combinations with iron and calcium, and in some silicates. It has not been met with native.

The ores are infusible alone before the blowpipe, or nearly so. Their specific gravity is between 3·0 and 4·5.

Rutile.

Tetragonal; in prisms of four, eight, or more sides, with pyramidal terminations; often acicular and penetrating quartz; often twinned as in the figure and in other groupings (p.59; $1 \wedge 1 =$) 123° 7½′. Sometimes massive. Cleavage lateral, somewhat distinct.



Color reddish brown to nearly red; streak very pale brown. Lustre submetallic-adamantine. Transparent to opaque. Brittle. H. = 6–6·5. G. = 4·18–4·22; black, 4·24–4·25.

Composition. TiO_2 = Oxygen 39, titanium 61 = 100. This composition is that also of octahedrite and brookite (next page); the species differ in crystallization and other physical characters. Sometimes contains iron, and has nearly a black color (*Nigrine*). B.B. alone unaltered; with salt of phosphorus a colorless bead, which in the reducing flame becomes violet on cooling.

Diff. The peculiar subadamantine lustre of rutile, and brownish-red color, in splinters much lighter red, are striking characters. It differs from tourmaline, idocrase, and augite, by being unaltered when heated alone before the blowpipe; and from tin ore, in not affording tin with soda; from sphene in its crystals.

Obs. Occurs in granite, gneiss, mica schist, syenyte, and in granular limestone. Sometimes associated with hematite, as at the Grisons. Occurs at Yrieix, France; Castile; Brazil; Arendal, Norway.

In the United States, it occurs in crystals at Warren, Me.; Lyme and Hanover, N. H.; Barre, Windsor, Shelburne, Leyden, Conway, Mass.; Monroe and Huntington, Ct.; near Edenville, Warwick, Amity, Kingsbridge, and in Essex Co. at Gouverneur, N. Y.; in Chester Co., Pa.; District of Columbia, at Georgetown; Buncombe and Alexander Cos., N. C.; Lincoln and Habersham Cos., Ga.; Magnet Cove, Ark.

Quartz crystal penetrated by long acicular crystals (*Sagenite*) are often very handsome when polished. A remarkable specimen of this kind was obtained in Northern Vermont, and less handsome ones are not uncommon; they

are found in N. Carolina. Polished stones of this kind are called in France *flèches d'amour* (love's arrows).

This ore is employed in painting on porcelain, and quite largely for giving the requisite shade of color and enamel appearance to artificial teeth; some kinds make fine though nearly opaque gems.

Octahedrite (*Anatase*). Tetragonal; in slender nearly transparent acute octahedrons; $1 \wedge 1 = 97° 51'$; H. = 5·5-6; G. = 3·8-3·95; color brown. Dauphiny; the Tyrol; Brazil; Smithfield, R. I.; Brindletown, Burke Co., N. C.

Brookite. In thin hair-brown flat orthorhombic crystals; also in thick iron-black crystals, as in the variety called *Arkansite;* H. = 5·5–6. Dauphiny; Snowdon in Wales; Ellenville, Ulster Co., N. Y.; Paris, Me.; gold washings, N. C.; Magnet Cove, Ark. (Arkansite.)

Pseudobrookite. In thin tabular brown to black crystals from Transylvania and Monte Dore. Much like brookite, but containing 4·23 p. c. of Fe_2O_3.

Perofskite. In cubic crystals, light yellow, brown, and black; formula $(Ti, Ca)_2O_3$. Urals; Tyrol; Magnet Cove, Ark.

Besides the ores here described, titanium is an essential constituent also of *menaccanite* (titanic iron), and of the silicates *titanite* or *sphene* (p. 290), *keilhauite* (p. 291), *warwickite;* and occurs also in the zirconia and yttria ores *æschynite, cerstedite,* and *polymignite,* and in some other rare species; sometimes in *pyrochlore.*

COBALT. NICKEL.

Cobalt has not been found native. The ores of cobalt are sulphides, arsenides, arseno-sulphides, an oxide, a carbonate, a phosphate, and an arsenate; and nickel is often associated with cobalt in the sulphides and arsenides. The ores having a metallic lustre vary in specific gravity from 6·2 to 7 2; are nearly tin-white or pale steel-gray, inclined to copper-red in color. The ores without a metallic lustre have a clear red or reddish color, and specific gravity of nearly 3. Cobalt is often present also in arsenopyrite (or mispickel), and sometimes in pyrite.

The ores of nickel are sulphides, arsenides, arseno-sulphides, and antimono-sulphides, a sulphate, carbonate, silicates, arsenate; and the metal is a constituent of several cobalt ores, and also often of pyrrhotite (magnetic pyrites). Specific gravity between 3 and 8; hardness of one, 3, but mostly between 5 and 6. Those of metallic lustre resemble some cobalt ores; but they do not give a deep-blue color with borax. Alloys of nickel and iron occur in meteorites (p. 189).

SULPHIDES, ARSENIDES, ANTIMONIDES, TELLURIDES.

Linnæite.—Cobalt Sulphide. Cobalt and Nickel Sulphide.

Isometric. In octahedrons and cubo-octahedrons; also massive. Color pale steel-gray, tarnishing copper-red. Streak blackish gray. H. = 5·5. G. = 4·8–5.

Composition. Co_3S_4 = Sulphur 42·0, cobalt 58·0 = 100; part of the cobalt replaced by nickel; copper sometimes present. *Siegenite* contains 30 to 40 per cent. of nickel. B.B. on charcoal yields sulphurous odor and a magnetic globule; often also arsenical fumes.

Obs. From Sweden; Siegen, Prussia; Mine la Motte, Mo. (*Siegenite*); Mineral Hill, Md. Sometimes called *Cobalt pyrites*. *Carrollite* is cobalt-copper pyrites.

Millerite.—Nickel Sulphide. Capillary Pyrites.

Rhombohedral. Usually in capillary or needle-like crystallizations; sometimes like wool; often in divergent tufts. Also in fibrous crusts; color brass-yellow, inclining to bronze-yellow, with often a gray iridescent tarnish. Streak bright. Brittle. H. = 3–3·5. G. = 5·65.

Composition. NiS = Sulphur 35·6, nickel 64·4 = 100. In the open tube sulphurous fumes. B.B. on charcoal fuses to a globule; after roasting, gives, with borax and salt of phosphorus, a violet bead in O.F., which in R.F. becomes gray from reduced metallic nickel.

Obs. From Joachimstahl, Przibram, Riechelsdorf; Saxony; Cornwall; at the Sterling Mine, Antwerp, N. Y.; at the Gap Mine, Lancaster Co., Pa.; at St. Louis, Mo., in capillary forms, and sometimes wool-like, in cavities in magnesian limestone; Nevada. A valuable ore of nickel.

Beyrichite. Hexagonal?; a nickel sulphide with Ni 56·79 p. c.

Polydymite. In isometric octahedrons; brilliant metallic; gray; nickel sulphide. Grünau, Westphalia.

Smaltite.—Cobalt Glance. Chloanthite.

Isometric. In octahedrons, cubes, dodecahedrons, and other forms; see Figs. 1, 2, 3, page 18, and 17, 27, page 21. Cleavage octahedral, somewhat distinct. Also reticulated; often massive.

Color tin-white, sometimes inclining to steel-gray. Streak grayish black. Brittle. Fracture granular and uneven. H. = 5·5–6. G. = 6·4–6·9, mostly; also 7·2.

Composition. (Co, Ni) As_2; the ore being either a *cobalt* arsenide, or *cobalt-nickel* arsenide; and graduating into the *nickel* arsenide called *Chloanthite.* The cobalt in the ore varies from 23·5 per cent. to none; iron often replaces part of the other metals.

In the closed tube gives metallic arsenic; in the open tube, a white sublimate of arsenous oxide, and sometimes traces of sulphurous acid. B.B. on charcoal an arsenical odor, fuses to a globule which gives reaction for iron, cobalt, and nickel.

Diff. Arsenopyrite (mispickel) is white like smaltite, but yields sulphur as well as arsenic, and in a closed tube affords the arsenic sulphides, orpiment and realgar.

Obs. Usually in veins with ores of cobalt, silver, and copper. Occurs in Saxony, especially at Schneeberg; also in Bohemia, Hessia, and Cornwall. In the U. States, found sparingly in gneiss, with niccolite, at Chatham, Ct.; in Gunnison Co., Col.

Cobaltite.

Isometric. Crystals like those of pyrite, but silver-white with a tinge of red, or inclined to steel-gray. Streak grayish black. Brittle. H. = 5·5. G. = 6–6·3.

Composition. $CoS_2 + CoAs_2 = CoAsS$ = Arsenic 45·2, sulphur 19·3, cobalt 35·5 = 100, but often with much iron and occasionally a little copper. Unaltered in the closed tube; but in the open tube, yields sulphurous fumes and a white sublimate of arsenous oxide. B.B. on charcoal yields sulphur and arsenic and a magnetic globule; with borax a cobalt-blue globule.

Diff. Unlike smaltite affords sulphur, and has a reddish tinge in its white color.

Obs. From Sweden, Norway, Siberia, and Cornwall. Most abundant in the mines of Wehna in Sweden, first opened in 1809.

Niccolite.—Copper Nickel. Arsenical Nickel.

Hexagonal. Usually massive. Color pale copper-red. Streak pale brownish-red. Lustre metallic. Brittle. H. = 5–5·5. G. = 7·35–7·67.

Composition. NiAs = Nickel 44, and arsenic 56; part of the arsenic may be replaced by antimony. B.B. gives off arsenical fumes, and fuses to a pale globule, which

darkens on exposure. Assumes a green coating in nitric acid, and is dissolved in aqua-regia. *Arite* is an antimonial variety from Balen, Pyrenees.

Diff. Distinguished from pyrite and linnæite by its pale reddish shade of color, and also its arsenical fumes, and from much of the latter by not giving a blue color with borax. None of the ores of silver with a metallic lustre have a pale color, excepting native silver itself.

Obs. Accompanies cobalt, silver, and copper ores in the mines of Saxony, and other parts of Europe; also sparingly in Cornwall. Found at Chatham, Ct., in gneiss, associated with white nickel or cloanthite; in Churchill Co., Nev., abundant, near Lovelock's station, on the Central Pacific R. R.

Skutterudite. Cobalt arsenide, $CoAs_3$. Skutterud, Norway.

Safflorite (*Spathiopyrite*). Cobalt-iron arsenide; orthorhombic; tin-white. Bieber, Germany.

Breithauptite or *Antimonial Nickel.* Hexagonal; pale copper-red, inclining to violet; H. = 5·5–6; G. = 7·54; NiSb = Antimony 67·8, nickel 32·2 = 100. Andreasberg.

Gersdorffite (*Nickel glance*). A nickel arsenosulphide; $NiS_2 + NiAs_2 = NiAsS$ = Arsenic 45·5, sulphur 19·4, nickel 35·1, but varying much in composition; sulphur-white to steel-gray; H. = 5·5; G. = 5·6–6·9. Loos, Sweden; the Hartz; Styria; Thuringia. *Sommarugaite* is an *auriferous* kind from Hungary.

Ullmannite or *Nickel Stibine.* An antimonial nickel sulphide, containing 25 to 28 p. c. of nickel; steel-gray, inclining to silver-white; in cubes, and massive; H. = 5–5·5; G. = 6·25–6·5. Duchy of Nassau.

Grünauite or *Bismuth Nickel.* A sulphide containing 31 to 38·5 of sulphur, 10 to 14 per cent. of bismuth, with 22 to 40·7 of nickel; light steel-gray to silver-white; often tarnished yellowish; H. = 4·5; G. = 5·13. Altenkirchen, Prussia.

Melonite. Nickel telluride; reddish white. Calaveras and Bowlder Cos., Cal.

Oxide.

Asbolite.—Earthy Cobalt. Black Cobalt Oxide.

Earthy, massive. Color black or blue-black. Soluble in muriatic acid, with an evolution of fumes of chlorine.

Obs. Occurs in an earthy state mixed with oxide of manganese as a bog ore, or secondary product. Abundant at Mine La Motte, Missouri, and also near Silver Bluff, South Carolina. The analyses vary in the proportion of oxide of cobalt associated with the manganese, as the compound is a mere mixture. Sulphide of cobalt occurs with the oxide.

The Carolina ores afforded cobalt oxide 24, manganese oxide 76. The ore from Missouri, as analyzed by B. Silliman, afforded 40 per cent. of cobalt oxide, with oxides of nickel, manganese, iron and copper.

This ore has been found abroad in France, Germany, Austria, and England.

The ore is purified and made into smalt, for the arts.

Heterogenite. Black; reniform; contains 78 p. c. cobalt oxide, and 21·33 of water. Schneeberg.

Heubachite. Mixture of oxides of cobalt, nickel and iron, with water.

Arsenates, Sulphates, Carbonates, Silicates.

Erythrite.—Cobalt Bloom. Hydrous Cobalt Arsenate.

Monoclinic. In oblique crystals having a highly perfect cleavage, like mica; laminæ flexible in one direction. Also as an incrustation; in reniform shapes; stellate.

Color peach-red, crimson-red, rarely grayish or greenish; streak a little paler, the dry powder lavender-blue. Lustre of laminæ pearly; earthy varieties without lustre. Transparent to subtranslucent. H. = 1·5–2. G. = 2·95.

Composition. $Co_3O_8As_2 + 8aq$ (or $3CoO + As_2O_5 + 8aq$) = Arsenic acid 38·4, oxide of cobalt 37·6, water 24·0. B.B. on charcoal, arsenical fumes and fuses; a blue glass with borax.

The earthy ore is sometimes called *peach-blossom ore*, from its color; and *red cobalt ochre*. *Köttigite* is a kind containing zinc.

Diff. Resembles red antimony, but that species wholly volatilizes before the blowpipe. Red copper ore differs in color and in giving a blue glass with borax; moreover, the color of the copper ore is more sombre.

Obs. Occurs with ores of lead and silver, and other cobalt ores, at Schneeberg, Saxony; Saalfield, Thuringia; Riechelsdorf, in Hessia; Dauphiny; Cornwall; Cumberland; near Lovelock's station on U. P. R. R., Nevada; Compton, Cal.

Valuable as an ore of cobalt when abundant.

Roselite. Cobalt arsenate; rose-red; triclinic. Schneeberg.

Cobaltomenite. Cobalt selenite. Cacheuta, S. A.

Annabergite. Nickel arsenate; apple-green. Allemont, Dauphiny; Annaberg; Riechelsdorf; Nevada.

Cabrerite. Hydrous nickel arsenate. Laurium, Greece.

Bieberite (*Cobalt Vitriol*). Flesh-red, rose-red; taste astringent;

$CoO_4S + 7aq$ (or $CoO + SO_3 + 7aq$) = Sulphuric acid 28·4, cobalt oxide 25·5, water 46·1. Bieber, near Hanau; Salzburg; Chili.

Morenosite (*Nickel Vitriol*). $NiO_4S + 7aq$; apple-green, greenish.

Lindackerite. Hydrous nickel-copper arsenate.

Zaratite (*Emerald Nickel*). Incrusting, minute globular or stalactitic; bright emerald-green; lustre vitreous; transparent or nearly so; H. = 3–3·25; G. = 2·5–2·7; nickel carbonate, containing nearly 30 per cent. of water; B. B. infusible alone, but loses its color. With chromite on serpentine, Lancaster Co., Pa.

Remingtonite. Hydrous cobalt carbonate; rose-colored. Finksburg, Md.

Spherocobaltite. Cobalt carbonate, CoO_2C (or $CoO + CO_2$); black to red. Saxony.

NICKEL SILICATES. *Genthite* is a hydrous magnesium-nickel silicate, pale apple-green, yielding in one analysis 30 per cent. of nickel oxide; from Texas, Lancaster Co., Pa., and other localities. *Röttisite*, from Röttis, Voigtland, is similar. *Pimelite* is an impure apple-green silicate, affording in one case 15·6 per cent. of nickel oxide. *Alipite* and *Avalite* are similar; so also *Garnierite* (and *Noumeite*), from New Caledonia, and worked there for nickel. A similar ore occurs 8 m. from Canonville in S. Oregon, in serpentine.

General Remarks.—The two arsenical ores of cobalt afford the greater part of the cobalt of commerce. The earthy oxide when abundant is a profitable source of the metal. Erythrite (Cobalt Bloom) occurs abundantly with other cobalt ores at its localities in Saxony, Thuringia and Hesse Cassel. Arsenopyrite (mispickel) yields at times 5 to 9 per cent. of cobalt. Nearly all the cobalt used in the U. States is imported. Mine La Motte afforded $12,500 worth in 1882, and the works at Camden, Pa., about 3 times this amount. The value of the metal is a little less than $3 a pound.

Cobalt is never employed in the arts in a metallic state, as its alloys are brittle and unimportant. It is chiefly used for painting on porcelain and pottery, and for this purpose it is mostly in the state of an oxide, or the silicated oxide called smalt and azure. *Thenard's blue*, or cobalt ultramarine, is made on the large scale by heating a mixture of phosphate or arsenate of cobalt and alumina. *Zaffre* is an impure oxide obtained in the calcining of the ore with twice its weight of sand; and from it the smalt and azure are produced.

Nickel is worked in Germany, Austria, Russia, Sweden, England, United States, and New Caledonia. It is obtained largely from the copper nickel (niccolite) and chloanthite, or from an artificial product called *speiss* (an impure arsenide), derived from roasting ores of cobalt containing nickel; from siegenite (or nickel-linnæite), a sulphide of cobalt and nickel; from millerite, in part; from the apple-green silicate; and largely from pyrrhotite or "magnetic iron pyrites." At the Gap Mine, near Lancaster, Pa., the ore is pyrrhotite with millerite; and the nickel produced from the mine in 1884 was 64,550 lbs.; this was smelted at the American Nickel Works, at Camden, N. J., the only nickel works in the U. States. In Missouri, the ore is siegenite; in New Caledonia, chiefly the silicate.

Nickel often occurs with chrome ores in serpentine rocks; it also

occurs in meteoric iron, forming an alloy with the iron, which is characteristic of most meteorites. The proportion sometimes exceeds 20 per cent.

As nickel does not rust or oxidize (except when heated), it is superior to steel for the manufacture of many philosophical instruments. An alloy of copper, nickel, and zinc (one-sixth to one-third nickel), constitutes the *German silver*, or *argentane*.

"German silver" is not a very recent discovery. In the reign of William III. an act was passed making it felony to *blanch copper* in imitation of silver, or mix it with silver for sale. "*White copper*" has long been used in Saxony for various small articles; the alloy employed is stated to consist of copper 88·00, nickel 8·75, sulphur with a little antimony 0·75, silex, clay, and iron 1·75. A similar alloy is well known in China, and is smuggled into various parts of the East Indies, where it is called *packfong*. It has been sometimes identified with the Chinese *tutenague*. M. Meurer analyzed the white copper of China, and found it to consist of copper 65·24, zinc 19·52, nickel 13, silver 2·5, with a trace of cobalt and iron. Dr. Fyfe obtained copper 40·4, nickel 31·6, zinc 25·4, and iron 2·6. It has the color of silver, and is remarkably sonorous. It is worth in China about one fourth its weight of silver, and is not allowed to be carried out of the empire.

An alloy of 75 per cent. copper and 25 per cent. nickel is the material of the United States cent. Switzerland, Belgium, Germany, Mexico, and Jamaica also use a nickel alloy for coins.

Nickel is largely used at the present time for nickel-plating by electro-deposition. The value of the metal in commerce rose in the years 1870 to 1875, from $1.25 to $3.00 per pound; but since 1880 it has been $1 to $1.10.

URANIUM.

Uranium ores have a specific gravity not above 10, and a hardness below 6. The ores are either of some shade of light green or yellow, or they are dark brown or black and dull, or submetallic and without a metallic lustre when powdered. They are not reduced when heated with carbonate of soda; and the brown or black species fuse with difficulty on the edges or not at all.

Uraninite.—Pitchblende. Uranium Oxide.

Isometric. In octahedrons and related forms. Also massive and botryoidal. Color grayish, brownish, or velvet-black. Lustre submetallic or dull. Streak black. Opaque. H. = 5·5. G. =, when unaltered, 9·2–9·3 (from Branchville).

Composition. Branchville crystals, U 81·50, O 13·47, Pb 3·97, Fe 0·40, H_2O 0·88 = 100·22. Mineral usually altered and impure, with G. 6·4–8. B.B. infusible; a gray

scoria with borax. Dissolves slowly in nitric acid when powdered.

Obs. Occurs in veins with ores of lead and silver in Saxony, Bohemia, and Hungary; also in the tin-mines of Cornwall, near Redruth. In the United States, at Branchville, in brilliant octahedrons; very sparingly at Middletown and Haddam, Ct.; in N. Carolina; on the north side of Lake Superior (*Coracite*); in Gilpin Co., near Central City, Col., with torbernite and other uranium ores (common results of its alteration), where, in 1872, a large body of it was thrown out of a shaft, and 3 tons sold in England for $1.50 per pound.

The oxides of uranium are used in painting upon porcelain, yielding a fine orange in the enamelling fire, and a black color in that in which the porcelain is baked. Bohemia is the chief source of it.

Cleveite. Hydrated oxide of uranium, iron, erbium, cerium, yttrium; isometric, like spinel. Norway. *Bröggerite* is related; from Norway.

Gummite. An amorphous uranium ore, looking like gum, of a reddish or brownish color; a hydrous uraninite. Johanngeorgenstadt; N. Carolina.

Eliasite. Like gummite, more or less resin-like in aspect; reddish-brown to black. Elias Mine, Joachimstahl.

Hatchettolite. Hydrous niobo-tantalate of uranium; in isometric octahedrons; resembles pyrochlore; G. = 4·76–4·84. Mitchell Co., North Carolina.

Blomstrandite. Hydrous titano-niobate; black. Sweden.

Torbernite.—Uranite. Chalcolite. Uran-Mica.

Tetragonal. In square tables, thinly foliated parallel to the base, almost like mica; laminæ brittle.

Color emerald and grass-green; streak a little paler. Lustre of laminæ pearly. Transparent to subtranslucent. H. = 2–2·5. G. = 3·3–3·6.

Composition. A uranium-copper phosphate, consisting if pure of Phosphorus pentoxide 15·1, uranium trioxide 61·2, copper oxide 8·4, water 15·3 = 100. B.B. fuses to a blackish mass, and colors the flame green.

Diff. The micaceous structure, bright green color and square tabular form of the crystals are striking characters.

Obs. Occurs with uranium, silver and tin ores. It is found at St. Symphorien, in splendid crystallizations, near Redruth and elsewhere in Cornwall; in the Saxon and Bohemian mines; in North Carolina.

Autunite. Similar to torbernite and often occurring with it; color bright citron-yellow; a uranium-calcium phosphate; G. = 3–3·2. Near Autun in France; sparingly, Portland, Middletown; good at Branchville, Ct.; Acworth, N. H.; Chesterfield, Mass.; and in N. Carolina.

Uranospinite is an autunite containing arsenic instead of phosphorus; and *Zeunerite,* a torbernite containing arsenic instead of phosphorus.

Phosphuranylite. Hydrous uranium-lead phosphate; lemon-yellow. Mitchell Co., N. C.

Samarskite, Euxenite, Annerödite. See p. 221.

Johannite or *Uranvitriol.* A uranium sulphate; fine emerald green; taste bitter. Bohemia. *Uranochalcite, Medijdite, Zippeite, Voglianite, Uraconite,* are other uranium sulphates.

Trögerite and *Walpurgite* are uranium arsenates. *Voglite* and *Liebigite* are uranium carbonates.

Uranocircite (*Baryturanite*) is a hydrous barium-uranium phosphate. *Uranothallite* is a hydrous uranium-lime carbonate; and *Schröckeringite* is similar.

Uranotil. A hydrous uranium-calcium silicate; G. = 3·8–3·9; Saxony; Mitchell Co., N. C. *Uranopilite,* a hydrous calcium-uranium silicate; from Saxony. *Randite,* a doubtful yellow uranium compound; near Philadelphia, Pa. *Uranothorite* is a thorite containing uranium; from the Champlain iron region, N. Y.

IRON.

Iron occurs native, and alloyed with nickel in meteoric iron. Its most abundant ores are the oxides and sulphides. It is also found combined with arsenic, forming arsenides and sulpharsenides; with oxygen and other metals, as chromium, aluminum, magnesium; and in the condition of sulphate, phosphate, arsenate, niobate, tantalate, silicate, and carbonate, of which the last is an abundant and valuable ore. Its ores are widely disseminated. The oxides and silicates are the ordinary coloring ingredients of soils, clays, earth, and many rocks, tingeing them red, yellow, dull green, brown, and black.

The ores have a specific gravity below 8, and the ordinary workable ores seldom exceed 5. Many of them are infusible before the blowpipe, and nearly all minerals containing iron become attractable by the magnet after heating, B.B. in the inner flame, when not so before. By their difficult fusibility, the species with a metallic lustre are distinguished from ores of silver and copper, and also more decidedly from these and other ores by blowpipe reaction.

Native Iron.

Isometric. Usually massive with octahedral cleavage.

Color and streak iron-gray. Fracture hackly. Malleable and ductile. H. = 4·5. G. = 7·3–7·8. Acts strongly on the magnet.

Obs. Native iron occurs in grains disseminated through some doleryte, basalt, and other related igneous rocks (as in Connecticut); and in Greenland, in very large masses in such igneous rocks, the largest weighing over a ton. It is suggested by J. Lawrence Smith, that the iron was reduced by means of carbohydrogen vapors, taken into the rock from carbonaceous rocks passed through on the way to the surface.

It is a constituent of nearly all meteorites, and the chief ingredient in a large part of them; and in this state it is with a rare exception alloyed with nickel, and with traces of cobalt and copper. The Texas meteorite, of Yale College, weighs 1635 pounds; the Pallas meteorite, now at Vienna, originally 1600; but one in Mexico, the San Gregorio meteorite, is stated to weigh five tons; and one in the district of Chaco-Gualamba, S. A., nearly *fifteen tons.* Meteoric iron often has a very broad crystalline structure, long lines and triangular figures being developed by putting nitric acid on a polished surface. The coarseness of this structure differs in different meteorites, and serves to distinguish specimens not identical in origin. Nodules of troilite (FeS), and schreibersite (iron phosphide) are common in iron meteorites. Meteoric iron may be worked like ordinary malleable iron. The nickel diminishes the tendency to rust. But some kinds contain iron chloride, or are open in texture, and rust badly. *Chamasite, Tœnite, Oktibehite, Edmonsonite,* are names given to different alloys of nickel and iron found in meteorites.

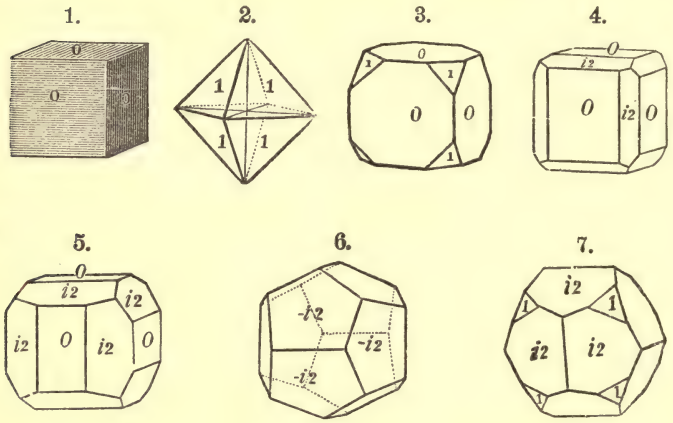
Sulphides, Arsenides, Tellurides, Chlorides.

Pyrite.—Iron Pyrites. Iron Disulphide.

Isometric. Usually in cubes, the striæ of one face at right angles with those of either adjoining face, as in Fig. 1. Also Figs. 2 to 7; also Figs. 8 to 15 on page 20. Fig. 6, a pentagonal dodecahedron, is a common form. Occurs also in imitative shapes, and massive.

Color brass-yellow; streak brownish-black. Lustre often splendent metallic. Brittle. H. = 6–6·5, will strike fire with steel. G. = 4·8–5·2; purest 5·1–5·2.

Composition. FeS_2 = Sulphur 53·3, iron 46·7 = 100.



B.B. on charcoal gives off sulphur, and ultimately affords a globule attractable by the magnet.

Pyrite often contains a minute quantity of gold, and is then called *auriferous pyrite.* See under Gold. Nickel, cobalt, and copper occur in some pyrite.

Diff. Distinguished from copper pyrites in being too hard to be cut by a knife, and also in its paler color. The ores of silver at all resembling pyrite are steel-gray or nearly black; and besides, they are easily scratched with a knife and quite fusible. Gold is sectile and malleable.

Obs. Pyrite is one of the most common of ores. Occurs in rocks of all ages. Cornwall, Elba, Piedmont, Sweden, Brazil, and Peru have afforded magnificent crystals. Alston Moor, Derbyshire, Kongsberg in Norway, are well-known localities. It has also been observed in the Vesuvian lavas, and in many other igneous rocks. It is mined largely in Spain and Portugal, particularly at the Rio Tinto mine.

Fine crystals have been met with at Rossie, N. Y., and at many other places in that State; also in each of the New England States and in Canada; in New Jersey, Pennsylvania,

Virginia, North Carolina, Georgia, in Colorado, Wyoming, and the States west. It occurs in all gold regions, and is one source of gold. A vein is worked in Rome, near Charlemont, Mass.; several in Louisa Co., Va.; in Georgia; at Capelton, Canada.

This species is of high importance in the arts, although not affording good iron on account of the difficulty of separating all the sulphur. It affords the greater part of the sulphate of iron (green vitriol or copperas) and sulphuric acid (oil of vitriol) of commerce, and also a considerable portion of the sulphur and alum. To make the sulphate the pyrites are sometimes heated in clay retorts, by which about 17 per cent. of sulphur is distilled over and collected. The ore is then thrown out into heaps, exposed to the atmosphere, when a change ensues by which the remaining sulphur and iron become through oxidation sulphate of iron. The material is lixiviated, and partially evaporated, preparatory to its being run off into vats or troughs to crystallize. In other instances, the ore is coarsely broken up and piled in heaps and moistened. Fuel is sometimes used to commence the process, which afterwards the heat generated continues. Decomposition takes place as before, with the same result. Cabinet specimens of pyrite, especially the granular or amorphous masses, often undergo a spontaneous change to the sulphate, particularly when the atmosphere is moist.

Pyrite, owing to its tendency to oxidation, and its very general distribution in rocks of all kinds and ages, is one of the chief sources of the disintegration and destruction of rocks. No granite, sandstone, slate, or limestone, containing it is fit for architectural purposes or for any outdoor use. The same destructive effects come from pyrrhotite and marcasite, which also are widely diffused.

The name *pyrites* is from the Greek *pur*, fire; because, as Pliny states, "there was much fire in it," alluding to its striking fire with steel. This ore is the *mundic* of miners.

Marcasite or *White iron pyrites.* Like pyrite in composition, but orthorhombic; $I \wedge I = 106^\circ\ 36'$; color a little paler; more liable to decomposition; hardness the same; G. = 4·6–4·85. *Radiated pyrites, Hepatic pyrites, Cockscomb pyrites* (alluding to its crested shapes), and *Spear pyrites*, are names of some of its varieties. In crystals at Warwick and Phillipstown, N. Y.; massive at Cummington, Mass.; Monroe, Trumbull, East Haddam, Ct.; Haverhill, N. H.

Pyrrhotite.—Magnetic Pyrites. Iron Sulphide.

Hexagonal. In tabular hexagonal prisms, and massive.

Color between bronze-yellow and copper-red; streak dark grayish black. Brittle. H. = 3·5–4·5. G. = 4·5–4·65. Slightly attracted by the magnet. Liable to speedy tarnish.

Composition. Fe_7S_8 = Sulphur 39·5, iron 60·5. It is often a valuable ore of nickel, containing sometimes 3 to 5 per cent. of this metal. B.B. on charcoal in the outer flame it is converted into red oxide of iron. In the inner flame it fuses and glows, and affords a black magnetic globule, which is yellowish on a surface of fracture.

Diff. Its inferior hardness and shade of color, and its magnetic quality distinguish it from pyrite; and its paleness of color from chalcopyrite or copper pyrites.

Obs. Found at Kongsberg, Norway; Andreasberg in the Hartz; massive in Cornwall; Saxony; Siberia; the Hartz; also at Vesuvius.

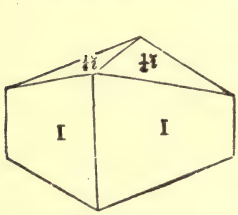
In the United States it is met with at Trumbull and Monroe, New Fairfield, and Litchfield, Ct.; New Marlboro and elsewhere, Mass.; Strafford and Shrewsbury, Vt.; Corinth, N. H.; Brewster, etc., N. Y.; Lancaster, Pa., where it is worked for nickel; Canada, at Elizabethtown, in crystals. It is used for making green vitriol and sulphuric acid, like pyrite.

Troilite. Like pyrrhotite, but having the formula FeS; occurs only in meteorites.

Schreibersite. Iron-nickel phosphide. In meteorites.

Arsenopyrite.—Mispickel. Arsenical Iron Pyrites.

Orthorhombic; $I \wedge I = 111° 40'$ to 112°. In rhombic prisms, with cleavage parallel to *I*. Crystals sometimes elongated horizontally, producing a rhombic prism of 100° nearly, with *I* and *I* the end planes. Also massive.



Color silver-white. Streak dark grayish black. Lustre shining. Brittle. H. = 5·5–6. G. = 5·67–6·3.

Composition. FeAsS = Arsenic 46·0, sulphur 19·6, iron 34·4 = 100. A *cobaltic* variety contains 4 to 9 per cent. of cobalt in place of part of the

iron; *Danaite* of New Hampshire consists of Arsenic 41·4, sulphur 17·8, iron 32·9, cobalt 6·5. B.B. affords arsenical fumes, and a globule of iron sulphide attractable by the magnet. In the closed tube a sublimate of arsenic sulphide. Gives fire with a steel and emits a garlic odor.

Diff. Resembles arsenical cobalt, but is much harder, it giving fire with steel; differs also in yielding a magnetic globule B.B.

Obs. Found mostly in crystalline rocks, and common with ores of silver, lead, iron, or copper. Worked for its arsenic, and sometimes also for cobalt and gold. Abundant at Freiberg, Munzig, and elsewhere in Europe, and also in Cornwall, England.

In crystals, at Franconia, Jackson, and Haverhill, N. H.; at Blue Hill Bay, Corinth, Newfield, and Thomaston, Me.; at Waterbury, Vt.; massive at Worcester and Sterling, Mass.; at Franklin, N. J.; in Lewis, Essex Co., and near Edenville and elsewhere in Orange Co., in Kent, Putnam Co., N. Y.; at Deloro, Canada, in crystals, and worked for arsenic.

Leucopyrite. Arsenical iron $FeAs_2$. Resembles the preceding in color and in its crystals; has less hardness and higher specific gravity; H. = 5–5·5; G. = 6·8–8·71. Contains arsenic 72·8, iron 27·2, with some sulphur. From Styria, Silesia, and Carinthia. Nickeliferous from Gunnison Co., Col.

Löllingite. Another iron arsenide, Fe_2As_3 = Arsenic 66·8, iron 33·2; G. = 6·2–7·45.

Berthierite. An iron sulphantimonite.

Orileyite. A doubtful steel-gray iron-copper arsenide. Burmah.

Ferrotellurite. Iron tellurite, FeO_4Te; tufts of minute prisms; yellow, greenish. Keystone Mine, Col.

Lawrencite. Iron protochloride. The Greenland native iron, and one cause of its rapid oxidization. Named after J. Lawrence Smith. *Stagmatite* is the same.

Molysite. Iron chloride, $FeCl_3$. Vesuvius.

Kremersite. Iron-potassium-ammonium chloride. Vesuvius.

Erythrosiderite. Hydrous iron-potassium chloride. Vesuvius. *Douglassite.*

Siderazote. Iron nitride, Fe_5N_2; an incrustation; lustre steel-like. Mt. Etna.

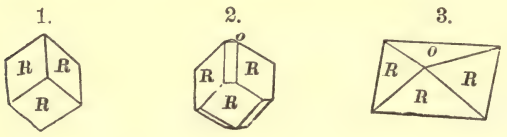
Oxides.

Hematite.—Specular Iron Ore. Iron Sesquioxide.

Rhombohedral; $R \wedge R = 86° 10'$ (Fig. 1). Crystals occasionally thin tabular. Cleavage usually indistinct. Often

massive granular; sometimes lamellar or micaceous. Also pulverulent and earthy.

Color dark steel-gray or iron-black. Lustre when crystallized splendent. Streak-powder cherry-red or reddish-



brown. The metallic varieties pass into a red earthy ore called red ochre, having none of the external characters of the crystals, but like them when they are pulverized. G. = 4·5–5·3. Hardness of crystals 5·5–6·5. Sometimes slightly attracted by the magnet.

VARIETIES.

Specular iron. Lustre perfectly metallic.

Micaceous iron. Structure foliated.

Red hematite. Submetallic, or unmetallic, brownish red.

Red ochre. Soft and earthy, and often containing clay.

Red chalk. More firm and compact than red ochre, and of a fine texture.

Jaspery clay iron. A hard impure siliceous clayey ore, and having a brownish red jaspery look and compactness.

Clay iron stone. The same as the last, the color and appearance less like jasper. But this is one variety only of what is called "clay iron stone," a name covering also a related variety of siderite and limonite.

Lenticular argillaceous ore. An oolitic red ore, consisting of small flattened grains.

Martite is hematite in octahedrons, derived, it is supposed, from the oxidation of magnetite.

Composition. Fe^2O^3 = Oxygen 30, iron 70 = 100. B.B. alone infusible; in the inner flame becomes magnetic.

Diff. The red powder of this mineral, and the magnetism which is so easily induced in it by the reduction flame distinguish hematite from all other ores. The word *hematite,* from the Greek *haima,* blood, alludes to the color of the powder. The powder of magnetite is black.

Obs. Occurs in crystalline and stratified rocks of all ages. The more extensive beds abound in Archæan rocks; while the argillaceous varieties occur in stratified rocks, being often abundant in coal regions and among other strata. Crystallized specimens are found also in some lavas, as a volcanic product.

Splendid crystallizations of this ore come from Elba, whose beds were known to the Romans; also from St. Gothard; Arendal, Norway; Longbanshyttan, Sweden; Lorraine and Dauphiny; Brazil (martite in part). Etna and Vesuvius afford handsome specimens.

In the United States an abundant ore. The two Iron Mountains of Missouri, situated 90 miles south of St. Louis, consist mainly of this ore, piled "in masses of all sizes from a pigeon's egg to a middle-sized church;" one 300 feet high, the other, the "Pilot Knob," 700 feet. Large beds occur in Essex, St. Lawrence, and Jefferson Cos., N. Y.; at Marquette, Mich.; the micaceous variety, at Hawley, Mass., Piermont, N. H., and in Stafford County, Va.; lenticular argillaceous ore abundantly in Oneida, Herkimer, Madison, and Wayne Cos., N. Y., constituting one or two beds of the Clinton group (Upper Silurian), in a compact sandstone; and the same is found in Pennsylvania and south to Alabama, and also in Wisconsin; it contains 50 per cent. of oxide of iron, with about 25 of carbonate of lime and more or less magnesia and clay. The coal region of Pennsylvania affords abundantly the clay iron ores, but they are mostly either the argillaceous carbonate or limonite.

Much of the Marquette ore is *martite*; and the Cerro de Mercado, of Mexico, is spoken of as a mountain of martite.

Valuable as an iron ore, though less easily worked when pure and metallic than the magnetic and hydrous ores. Pulverized red hematite is used for polishing metal. Red chalk is a well-known material for red pencils.

Menaccanite.—Ilmenite. Titanic Iron. Washingtonite.

Rhombohedral; $R \wedge R = 85° 31'$. Often in thin plates or seams in quartz; also in grains. Crystals sometimes very large and tabular.

Color iron-black. Streak submetallic. Lustre metallic or submetallic. H. = 5–6. G. = 4·5–5. Acts slightly on the magnetic needle.

Composition. Like that of hematite, except that part of the iron is replaced by titanium; the amount replaced is very variable. Infusible alone before the blowpipe.

Diff. Near hematite, but its powder is not red.

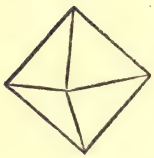
Obs. In Warwick, Amity, and Monroe, Orange Co., N.Y. Crystals, an inch in diameter; near Edenville and Greenwood Furnace; at South Royalston and Goshen, Mass.; at Washington, South Britain, and Litchfield, Ct.; at Westerly, R.I.; Magnet Cove, Ark; in Canada.

It is of no value in the arts, and is a deleterious constituent of many iron ores.

Magnetite.—Magnetic Iron Ore.

Isometric. Often in octahedrons (Fig. 1), and dodecahedrons (Fig. 2). Cleavage octahedral; sometimes distinct. Also granularly massive. Occasionally in dendritic forms between the folia of mica.

1.



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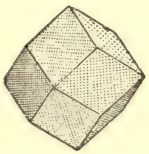


Color iron-black. Streak black. Brittle. H. = 5·5–6·5. G. = 5·0–5·1. Strongly attracted by the magnet, and sometimes having polarity.

Composition. $FeFeO_4 = FeO + FeO_3$ = Oxygen 27·6, iron 72·4 = 100. Infusible before the blowpipe. Yields a yellow glass when fused with borax in the outer flame.

Diff. The black streak and strong magnetism distinguish this species from the following.

Obs. Magnetic iron ore occurs in extensive beds, and also in disseminated crystals. It is met with in granite, gneiss, mica schist, clay slate, syenyte, hornblende, and chlorite schist; and also sometimes in limestone.

The beds at Arendal, and nearly all the Swedish iron ore, consist of massive magnetic iron. At Dannemora and the Taberg in Southern Sweden, and also in Lapland at Kurunavara and Gelivara, there are mountains composed of it.

In the U. States it constitutes extensive beds, in Archæan rocks, in Warren, Essex, Clinton, Orange, Putnam, Saratoga, and Herkimer Cos., N. Y.; and in Sussex and Warren Cos., N. J. Smaller deposits occur in the several New England States and Canada. Also found at Magnet

Cove, Ark.; in Sierra Co., Cal.; with hematite in the Iron Mountains of Missouri.

Masses of this ore, in a state of magnetic polarity, constitute what are called *lodestones* or *native magnets*. They are met with in many beds of the ore: in Siberia; the Hartz; the Island of Elba; at Marshall's Island, Me.; near Providence, R. I.; at Magnet Cove, Ark. The lodestone is called *magnes* by Pliny, from the name of the country, Magnesia (a province of ancient Lydia), where it was found; and it hence gave the terms *magnet* and *magnetism* to science.

Franklinite.

Isometric. In octahedral and dodecahedral crystals; also coarse granular massive. Color iron-black. Streak dark reddish brown. Brittle. H. = 5·5–6·5. G. = 4·5–5·1. Usually feebly attracted by the magnet.

Composition. General formula like that of magnetite, RRO_4, but having zinc and manganese replacing part of the iron, as indicated in the formula (Fe, Zn, Mn) (Fe, Mn) O_4. A common variety corresponds to Fe_2O_3 67·6, FeO 5·8, ZnO 6·9, MnO 9·7 = 100.

B.B. with soda on charcoal a zinc coating; a soda bead in the outer flame is colored green by the manganese.

Diff. Resembles magnetic iron, but the exterior color is a more decided black. The streak is reddish brown, and the blowpipe reactions are distinctive.

Obs. Abundant at Sterling and Hamburg, Sussex Co., N. J.; near Franklin Furnace, crystals sometimes 4 in. in diameter. Amorphous at Altenberg, near Aix-la-Chapelle.

Jacobsite. Isometric octahedrons; Fe, Mn, MnO; magnetic; Sweden.

Chromite.—Chromic Iron.

Isometric. In octahedrons; cleavage none. Usually massive, and breaking with a rough unpolished surface.

Color iron-black, brownish black. Streak dark brown. Lustre submetallic; often faint. H. = 5·5. G. = 4·32–4·6. In small fragments attractable by the magnet.

Composition. General formula RRO_4, as for magnetite, with part of the iron replaced by chromium. Analysis gives Iron protoxide 32, chromium sesquioxide 68 = 100; aluminium and magnesium also commonly present, replacing

the other constituents. B.B. infusible alone; with borax a beautiful green bead.

This ore usually possesses less metallic lustre than the other black iron ores.

Obs. Occurs usually in serpentine rocks, in imbedded masses or veins. Some of the foreign localities are the Gulsen Mountains in Styria; the Shetland Islands; the department of Var in France; Silesia; Bohemia, etc.

At Bare Hills, Soldier's Delight, and Owing's Mills, near Baltimore, at Cooptown in Harford Co., and north part of Cecil Co., Md.; in Townsend and Westfield, Vt.; at Chester and Blandford, Mass.; at Wood's Mine, near Texas, Lancaster Co., and in West Branford, Chester Co., Pa.; Jackson Co., N. C.; at Bolton and Ham, Canada East; San Luis Obispo, Napa, Del Norte, Sonoma (near New Idria), and Tuolumne Cos., Cal.; at Seattle in Wyoming.

The compounds of chromium, which are extensively used as pigments, are obtained chiefly from this ore; and the California mines afford nearly all that is used in the U. States; about 2500 tons were mined in 1882. The ore is shipped to Baltimore, and there nearly all is made into the bichromate for calico-printing and other purposes. Chrome green and chrome yellow, for use as pigments, are also manufactured there. About a third of the ore used at Baltimore, or near 2,000,000 lbs., is imported from Scotland.

Daubréelite. A black chromium sulphide. From meteorites.

Limonite.—Brown Hematite.

Usually massive; often smooth botryoidal or stalactitic, with a compact fibrous structure within. Also earthy.

Color dark brown and black to ochre-yellow; streak yellowish brown to dull yellow. Lustre when black sometimes submetallic; often dull and earthy; on a surface of fracture frequently silky. H. = 5–5·5. G. = 3·6–4.

The following are the principal varieties:

Brown hematite. The botryoidal, stalactitic and associated compact ore.

Brown ochre, Yellow ochre. Earthy ochreous varieties of a brown or yellow color.

Brown and *Yellow clay iron stone.* Impure ore, hard and compact, of a brown or yellow color.

Bog iron ore. A loose earthy ore of a brownish black color, occurring in low grounds.

Composition. $FeO_9H_6 (= 2FeO_3 + 3H_2O)$ = Iron sesquioxide 85·6, water 14·4 = 100; or a *hydrous* iron sesquioxide, containing, when pure, about two thirds its weight of pure iron. B.B. blackens and becomes magnetic; with borax in the outer flame a yellow glass.

Diff. A much softer ore than either of the two preceding, and peculiar in its frequent stalactitic forms, and in its affording water when heated in a glass tube.

Obs. Occurs connected with rocks of all ages, but appears, as shown by the stalactitic and other forms, to have resulted in all cases from the decomposition of other iron-bearing rocks or minerals.

An abundant ore in the United States. Extensive beds exist in Salisbury and Kent, Ct.; in Beekman, Fishkill, Dover, Amenia, N. Y.; in a similar situation in Richmond and West Stockbridge, Mass.; in Bennington, Monkton, Pittsford, Putney, and Ripton, Vt.; in Pennsylvania, the Carolinas, Virginia, and the region southwestward; also in Missouri, Iowa, Wisconsin, etc.

This is one of the most valuable ores of iron. The limonite of Western New England, and that along the same range geologically in Dutchess Co., New York, Eastern Pennsylvania, and beyond is remarkably free from phosphorus, and hence is highly valued for its iron. *Bog* ores usually contain much phosphorus, from organic sources, and hence the iron afforded is best fitted for castings. Limonite is also pulverized and used for polishing metallic buttons and other articles. As yellow ochre, it is a common material for paint.

Göthite (*Pyrrhosiderite*, *Lepidokrokite*). An iron hydrate, often in fine prismatic crystals, as well as fibrous and massive; G. = 4·0–4·4; streak brownish yellow; $FeO_4H_2 (= Fe_2O_3 + H_2O)$.

Turgite. Resembles limonite, but gives a reddish powder, and has the formula $Fe_2O_7H_2 = 2Fe_2O_3 + H_2O$; G. = 4·14. It occurs with limonite at the ore beds of Salisbury, Ct., and others in the same range. *Xanthosiderite* and *Limnite* are other related hydrates.

Melanosiderite. Hydrous iron sesquioxide, with 7·42 of silica; gelatinizes; lustre vitreous; fusible. From Mineral Hill, Pa.

Sulphates, Borate, Tungstate, Niobates, Tantalates.

Melanterite.—Copperas. Iron Vitriol. Green Vitriol.

Monoclinic; in acute oblique rhombic prisms. Cleavage basal, perfect. Generally pulverulent or massive.

Color greenish to white. Lustre vitreous. Subtransparent to translucent. Taste astringent and metallic. Brittle. H. = 2. G. = 1·83.

Composition. $FeO_4S + 7aq$ (or $FeO + SO_3 + 7aq$) = Sulphur trioxide 28·8, iron protoxide 25·9, water 45·3 = 100. B.B. becomes magnetic. Yields glass with borax. On exposure, becomes covered with a yellowish powder.

Obs. This species is the result of the decomposition of pyrite, marcasite and pyrrhotite, which readily afford it if moistened while exposed to the atmosphere, and it is obtained from these sulphides for the arts (p. 191). An old mine near Goslar, in the Hartz, is a noted locality. The variety *Luckite* contains some manganese; from Utah, Lucky Boy mine.

Copperas is much used by dyers and tanners, on account of its giving a black color with tannic acid, an ingredient in nutgalls and many kinds of bark. For the same reason, it forms the basis of ordinary *ink*, which is essentially an infusion of nutgalls and copperas. It is also employed in the manufacture of *Prussian blue*. In the United States the amount made in 1884 was about fifteen million pounds, but none of it from U. S. iron sulphides.

Coquimbite, Copiapite, Voltaite, Raimondite, Botryogen, Fibroferrite, Utahite, Ihleite, Clinophœite, Clinochrocite, are names of other hydrous iron sulphates; and *Halotrichite* is an iron-alum. *Utahite* is from the Tintic dist., Utah.

Jarosite. Hydrous iron-potassium sulphate. Spain; Chaffee Co., Col.

Sideronatrite. Hydrous iron-sodium sulphate; insoluble. Peru. *Urusite* is the same; Caspian Sea.

Pisanite. Iron-copper vitriol. Tuscany; Turkey.

Lagonite. Hydrous iron borate. From the Tuscan lagoons.

Wolframite.—Wolfram. Iron-manganese Tungstate.

Monoclinic. Also massive. Color dark grayish black. Streak dark reddish brown. Lustre submetallic, shining, or dull. H. = 5–5·5. G. = 7·1–7·5.

Composition. $(Fe,Mn)O_4W$ (or $(Fe,Mn)O + WO_3$). A typical variety affords tungsten trioxide 76·47, iron protoxide 9·49, manganese protoxide 14·04 = 100. B.B. fuses easily to a magnetic globule; with aqua regia dissolved with the separation of yellow tungsten trioxide. *Hübnerite* is a manganese wolframite, containing no iron; and *Ferberite* is an iron wolframite.

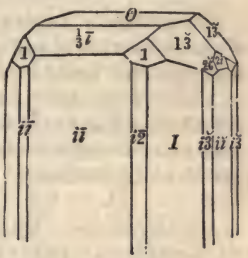
Found often with tin ores. Occurs in Cornwall; at Zinnwald and elsewhere. In the U. States, at Monroe and Trumbull, Ct.; on Camdage Farm, near Blue Hill Bay, Me.; near Mine La Motte, Mo.; at the Flowe Mine, N. C.; in Mammoth Mining district, Nev. (*Hübnerite*); the same in Ouray Co., Col., and in Montana.

The metal tungsten is employed to some extent in making with iron a kind of steel harder than ordinary steel. Soluble tungstates also have some uses in the arts.

Reinite. Like wolframite in composition, but tetragonal.

Columbite.

Orthorhombic; $I \wedge I$ over $i\text{-}\bar{i} = 100°\ 40'$, $I \wedge i\text{-}\bar{i} = 140°\ 20'$. In rectangular prisms, more or less modified. Also massive. Cleavage parallel to the lateral faces of the prism, somewhat distinct.



Color iron-black, brownish black; often with a characteristic iridescence on a surface of fracture. Streak dark brown, slightly reddish. Lustre submetallic, shining. Opaque. Brittle. H. = 5–6. G. = 5·4–6·5; also 6–6·85 when containing tantalum.

Composition. Iron niobate, of the formula FeO,Nb_2 (or $(R,Mn)O + Nb_2O_5$) = Niobium pentoxide 79·6, iron protoxide 16·4, manganese protoxide 4·4, tin oxide 0·5, lead and copper oxides 0·1 = 100. Tantalum often replaces part of the niobium. B.B. alone infusible. Imparts to the borax bead the yellow color due to iron.

Diff. Its dark color, submetallic lustre, and a slight iridescence, together with its breaking readily into angular fragments, will generally distinguish this species from the ores it resembles.

Obs. In granite at Bodenmais, Bavaria; in Bohemia; in the U. States, in granitic veins, at Middletown, Haddam, and Branchville, Ct.; Chesterfield, Beverly, and Northfield, Mass.; Acworth, N. H.; Greenfield, N. Y.; Standish, Me.; in granite veins in Amelia Co., Va.; at Pike's Peak, Col.; Black Hills, Dak. A crystal from Middletown originally weighed 14 pounds avoirdupois; a single mass occurred in the Black Hills weighing a ton (W. P. Blake).

This mineral was first made known from American specimens by Mr. Hatchett, an English chemist, and the new metal it was found to contain was named by him *columbium*.

Tantalite. $Fe(Mn)O_6Ta_2$; with sometimes tin and tungsten. Allied to columbite; H. = 6–6·5; G. = 7–8; being distinguished by its high specific gravity. Finland; Sweden; near Limoges in France; N. Carolina; Alabama. The Northfield and Branchville columbites are nearly tantalite in composition, and that of the Black Hills is probably the same species. *Mangantantalite* contains more manganese than iron.

Note.—The metal named *Columbium* by Hatchett is the same that was later called *Niobium*, without any good reason for the change of name.

Phosphates, Arsenates.

Vivianite.—Hydrous Iron Phosphate.

Monoclinic. In modified oblique prisms, with cleavage in one direction highly perfect. Also radiated, reniform, and globular, or as coatings.

Color deep blue to green and white. Crystals usually green at right angles with the vertical axis, and blue parallel to it. Streak bluish. Lustre pearly to vitreous. Transparent to translucent; opaque on exposure. Thin laminæ flexible. H. = 1·5–2. G. = 2·58–2·68.

Composition. $Fe_3O_8P_2 + 8$ aq (or $3FeO + P_2O_5 + 8$ aq) = Phosphorus pentoxide 28·3, iron protoxide 43·0, water 28·7 = 100. B.B. fuses easily to a magnetic globule, coloring the flame greenish blue. Affords water in a glass tube, and dissolves in hydrochloric acid. Changes by oxidation of the iron.

Diff. The deep-blue color and the little hardness are decisive characteristics. The blowpipe affords confirmatory tests.

Obs. Found with iron, copper and tin ores, and sometimes in clay, or with bog iron ore. St. Agnes in Cornwall, Bodenmais, and the gold-mines of Vöröspatak in Transylvania, afford fine crystallizations. In the U. States, in crystals at Imlaystown, N. J.; at Allentown, in Monmouth Co., Mullica Hill, in Gloucester Co., N. J. Often fills the interior of certain fossils. Also at Harlem, N. Y.; in Somerset and Worcester Cos., Md.; with bog ore in Stafford Co., Va. Abundant at Vaudreuil, Canada, with limonite. The *blue iron earth* is an earthy variety, containing about 30 p. c. of phosphoric acid.

Ludlamite. In monoclinic crystals; clear green; hydrous phosphate of iron. Cornwall. *Koninckite* is another, from Belgium.

Dufrenite. A hydrous phosphate of iron sesquioxide; color dull green; often in radiated forms. *Destinegite* is related to it; *Picite* also.

Cacoxenite. In radiated silky tufts; color yellow or yellowish brown; H. = 3–4; G. = 3·38; phosphate of iron sesquioxide; often contains alumina. Differs from wavellite, which it resembles, in its yellower color and iron reactions. Also resembles carpholite, but has a deeper color, and does not give the manganese reactions. On limonite in Bohemia.

Chalcosiderite and *Andrewsite* are other iron phosphates.

Richellite. Supposed to be an iron-calcium fluo-phosphate; G. = 2; cream-yellow. Richelle, Belgium.

Strengite. Hydrous iron phosphate, related in formula to scorodite; orthorhombic; reddish. Near Giessen, Germany.

Triphylite. An iron manganese-lithium phosphate. See p. 208.

Pharmacosiderite, or *Cube ore.* In cubes; dark green to brown and red; lustre adamantine, not very distinct; streak greenish, brownish; H. = 2·5; G. = 3. A hydrous arsenate of iron sesquioxide, containing 43 per cent. of arsenic pentoxide. Cornwall; France; Saxony; Hungary.

Scorodite. Orthorhombic; pale leek-green or liver-brown; vitreous to subadamantine; subtransparent to nearly opaque; H. = 3·5–4; G. = 3·1–3·3; a hydrous arsenate of iron sesquioxide. Saxony; Carinthia; Cornwall; Brazil; and minute crystals near Edenville, N. Y., with arsenical pyrites. Named from the Greek *skorodon*, garlic, alluding to the odor B.B. *Iron sinter* is an amorphous form of the same.

Arseniosiderite is another iron arsenate.

Emmonsite. Monoclinic?; yellowish green; G. about 5; probably tellurite of iron. Near Tombstone, Arizona.

Carbonates.

Siderite.—Spathic Iron. Iron Carbonate. Chalybite.

Rhombohedral; $R \wedge R = 107°$. Cleavage parallel to R easy. Faces often curved. Usually massive, with a foliated structure, somewhat curving. Sometimes in globular concretions or implanted globules.

Color grayish white to brown; often dark brownish red. Becomes nearly black on exposure. Streak uncolored. Lustre pearly Translucent to nearly opaque. H. = 3–4·5. G. = 3·7–3·9.

Composition. FeO_2C (or $FeO + CO_2$) = Carbon dioxide 37·9, iron protoxide 62·1 = 100. Often contains some manganese oxide or magnesia, and lime replacing part of the iron protoxide. B.B. it blackens and becomes magnetic;

but alone it is infusible. Dissolves in heated hydrochloric acid with effervescence. The iron, on exposure to the air, passes to the sesquioxide state, and usually to the hydrous iron sesquioxide (limonite), giving the siderite a brown or brownish yellow color.

The ordinary crystallized or foliated variety is called *spathic* or *sparry* iron, because the mineral has the aspect of a spar. The globular concretions found in some amygdaloidal rocks have been called *spherosiderite* because of its *spheroidal* forms. An argillaceous variety occurring in nodular forms is often called *clay iron stone,* and is abundant in coal measures.

Diff. Cleavage as in calcite and dolomite, but specific gravity higher. B.B. readily becomes magnetic.

Obs. Occurs in rocks of various ages, and often accompanies other ores. Large deposits and veins exist in gneiss and mica schist, clay slate; also in some limestone; in the Coal formation principally in the form of clay iron-stone. In Styria and Carinthia, abundant in gneiss; in the Hartz, in graywacke. Cornwall, Alstonmoor, and Devonshire are English localities.

In a vein in gneiss at Roxbury, Ct.; occurs also at Plymouth, Vt.; Sterling, Mass.; in Antwerp, Jefferson Co., and Hermon, St. Lawrence Co., N. Y.; in large masses in and beneath the limonite of Salisbury, Ct.; Amenia, N. Y.; W. Stockbridge, Mass.; being, it is supposed, part of the underlying limestone; abundant in a bed of limestone south of Hudson, N. Y., and now worked. Clay iron-stone is abundant in the coal regions of Pennsylvania and other coal-bearing States.

This ore is employed extensively for the manufacture of iron and steel.

Mesitite is an iron-magnesium carbonate.

Ankerite is like mesitite, but contains in addition a large percentage of calcium. Both make parts of many dolomitic limestones, and are the occasion of their becoming rusty and decomposed, producing limonite.

Humboldtine. A hydrous iron oxalate.

General Remarks.—The metal iron has been known from the most remote historical period, but was little used until the last centuries before the Christian era. Bronze, an alloy of copper and tin, was the almost universal substitute, for cutting instruments as well as weapons of war, among the ancient Egyptians and earlier Greeks; and even among the Romans (as proved by the relics from Pompeii), and also

throughout Europe, it continued long to be extensively employed for these purposes.

The *Chalybes*, bordering on the Black Sea, were workers in iron and steel at an early period; and near the year 500 B.C., this metal was introduced from that region into Greece, so as to become common for weapons of war. From this source we have the expression *chalybeate* applied to certain substances or waters containing iron.

The iron-mines of Spain have also been known from a remote epoch, and it is supposed that they have been worked "at least ever since the times of the later Jewish kings; first by the Tyrians, next by the Carthaginians, then by the Romans, and lastly by the natives of the country." These mines are mostly contained in the present provinces of New Castile and Aragon. Elba was another region of ancient works, "inexhaustible in its iron," as Pliny states, who enters somewhat fully into the modes of manufacture. The mines are said to have yielded iron since the time of Alexander of Macedon. The ore beds of Styria, in Lower Austria, were also a source of iron to the Romans.

The ores from which the iron of commerce is obtained are the siderite (spathic iron), magnetite (magnetic iron), hematite (specular iron), limonite ("brown hematite"), and bog iron ore. In England, the principal ore used is an argillaceous carbonate of iron, called often clay iron stone, found in nodules and layers in the coal measures. It consists of carbonate of iron, with some clay, and externally has an earthy, stony look, with little indication of the iron it contains except in its weight. It yields from 20 to 35 per cent. of cast iron. The coal basin of South Wales, and the counties of Stafford, Salop, York, and Derby, yield by far the greater part of the English iron. Brown hematite is also extensively worked. In Sweden and Norway, at the famous works of Dannemora and Arendal, the ore is the magnetic iron ore, and is nearly free from impurities as it is quarried out. It yields 50 to 60 per cent. of iron. The same ore is worked in Russia, where it abounds in the Urals. The Elba ore is the specular iron or hematite. In Germany, Styria, and Carinthia, extensive beds of spathic iron are worked. The bog ore is largely reduced in Prussia.

In the United States all these different ores are worked. The localities are already mentioned. The magnetic ore is reduced in New England, New York, Northern New Jersey, and sparingly in Pennsylvania, and other States. Limonite, or brown hematite, is largely worked along Western New England and Eastern New York, in Pennsylvania, and many States South and West. The earthy argillaceous carbonate like that of England, and the hydrate, are found with the coal deposits, and are a source of much iron.

The number of tons (2240 lbs.) of iron manufactured in the world in the year 1882 was about 21,000,000, of which Great Britain produced 8,500,000 tons, U. States 4,623,000 tons, Germany 3,171,000 tons, France 2,033,000 tons, Belgium 717,000 tons, Austria with Hungary 525,000 tons, Russia 450,000 tons, Sweden 440,000 tons, other countries 210,000. In 1860 the number of tons produced in the U. States was less than 900,000; in 1883, about 4,600,000; in 1884, 4,100,000.

MANGANESE.

The common ores of manganese are the oxides, the carbonate, and the silicates. There are also sulphides, an arsenide, and phosphates. Specific gravity not over 5·2.

Sulphides and Arsenides.

Alabandite or *Manganblende.* A manganese sulphide, MnS; iron black; streak green; lustre submetallic; H. = 3·5–4; G. = 3·9–4·0; crystals, cubes, and regular octahedrons. Gold-mines of Nagyag, Transylvania; Morococha, Peru; Summit Co., Col.

Hauerite. A sulphide, MnS^2; reddish brown, brownish black, resembling blende; H. = 4; G. = 3·46. Hungary.

Kaneite. Manganese arsenide; grayish white; metallic; B.B. gives off alliaceous fumes; G. = 5·55. Saxony.

Manganostibiite contains both arsenic and antimony. Sweden.

Oxides.

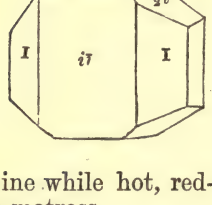
Manganosite.

Isometric crystals; cleavage cubic. Emerald green, but brown after exposure. Lustre vitreous. H. = 5–6. G. = 5.18.

Composition. MnO, or manganese protoxide. From Longban and Nordmark, Sweden.

Pyrolusite.—Manganese Dioxide. Black Oxide of Manganese.

Orthorhombic; $I \wedge I = 93° 40'$. In small rectangular prisms, more or less modified. Sometimes fibrous and radiated or divergent. Often massive and in reniform coatings. Color iron-black. Streak black, non-metallic. H. = 2–2·5. G. = 4·8.



Composition. MnO_2 = Manganese 63·2, oxygen 36·8 = 100. With a minute portion, borax bead deep amethystine while hot, red-brown on cooling. Yields no water in a matrass.

Diff. Differs from iron ores by the violet glass with borax.

Obs. Extensively worked in Thuringia, Moravia, and Prussia. Common in Devonshire and Somersetshire in

England, and in Aberdeenshire. In the United States, associated with the following species at Bennington, Brandon, Monkton, Chittenden, and Irasburg, Vt.; occurs also at Conway, Plainfield, and Richmond, Mass.; in Salisbury and Kent, Ct.; the Etowah region, Barton Co., Ga.; Augusta, Nelson, Rockingham, and Campbell Cos., Va.; the Crimora mine in Augusta Co., one of the best in the United States; on Red Island, in the Bay of San Francisco; at Pictou and Walton, N. Scotia; near Bathurst, in N. Brunswick.

Named *pyrolusite* from the Greek *pur*, fire, and *luo*, to wash, alluding to its property of discharging the brown and green tints of glass.

Hausmannite. A manganese oxide, $2MnO + MnO_2$, yielding 72·1 per cent. of manganese, when pure; brownish black; submetallic; massive and in tetragonal octahedrons; H. = 5–5·5; G. = 4·7. Thuringia; Alsatia.

Hetærolite. A zinc-hausmannite. Sterling Hill, N. J.

Braunite. A manganese oxide containing 69 per cent. of manganese when pure; color and streak dark brownish black; lustre submetallic; tetragonal octahedrons and massive; H. = 6–6·5; G. = 4·8. Piedmont; Thuringia.

Manganite. A hydrous manganese sesquioxide; massive and in rhombic prisms; steel-black to iron black; H. = 4–4·5; G. = 4·3–4·4. The Hartz; Bohemia; Saxony; Aberdeenshire; at several points in New Brunswick and Nova Scotia.

Crednerite. Cupreous manganese oxide.

Psilomelane.

Massive and botryoidal. Color black or greenish black. Streak reddish or brownish black, shining. H. = 5–6. G. = 4–4·4.

Composition. Essentially manganese dioxide with a little water, and some baryta or potassa; of varying constitution. B.B. like pyrolusite, except that it affords water. *Lithiophorite* is a lithia-bearing variety.

Obs. An abundant ore, associated usually with pyrolusite; the two often in alternating layers; has been considered impure pyrolusite. Named from the Greek *psilos*, smooth or naked, and *melas*, black.

Pyrochroite. Hydrous manganese protoxide, of white color; MnO_2H_2. Sweden.

Pelagite. The brownish black concretionary manganese nodules found in many regions over the bottom of the ocean; affords, according to an analysis, about 40 per cent. of MnO_2, 27 FeO_3, 13 of water

lost at a red heat, along with 14 per cent. of silica and 4 of alumina; 24·5 per cent. of water lost below 100° C. Probably a mixture.

Chalcophanite. A hydrous manganese zinc oxide in rhombohedral crystals and stalactites. Sterling Hill, Sussex Co., N. J.

Wad.—Bog Manganese.

Massive, reniform, earthy; in coatings and dendritic delineations. Color and streak black or brownish black. Lustre dull, earthy. H. = 1–6. G. = 3–4. Soils the fingers.

Composition. Manganese dioxide, in varying proportions, from 30 to 70 per cent., mechanically mixed with more or less of iron sesquioxide, and 10 to 25 per cent. of water. Often several p. c. of cobalt oxide present (var. *Asbolite*); and sometimes 4–18 p. c. of copper oxide (*Lampadite*). It is formed in low places from the decomposition of minerals containing manganese. Gives off much water when heated, and affords a violet glass with borax.

Obs. Wad occurs in Columbia and Dutchess counties, N. Y.; at Blue Hill Bay, Dover, Me.; at Nelson, Gilmanton, and Grafton, N. H.; and in many other parts of the country.

It may be employed like the preceding in bleaching, but is too impure to afford good oxygen. It may also be used for umber paint.

Sulphates.

Mallardite.

Fine, fibrous. Color white. Easily soluble.

Composition. Hydrous manganese sulphate, $MnO_4S + 7$ aq (or $MnO + SO_3 + 7$ aq).

Obs. From the Silver Mine Lucky Boy, Butterfield Cañon, Utah.

Szmikite. Another hydrous sulphate with less water. Transylvania.

Ilesite. Hydrous manganese zinc-iron sulphate; white; soluble. Hall Valley, Col.

Phosphates, Arsenates.

Triphylite.

Orthorhombic. In rhombic crystals, massive. Color greenish gray to bluish gray, but often brownish black ex-

ternally from the oxidation of the manganese present. Streak grayish white. Lustre subresinous. H. = 5. G. = 3·54–3·6.

Composition. A hydrous phosphate of iron, manganese and lithium, $(\frac{1}{4}Li_2\frac{3}{4}R)_3O_8P_2$, in which R stands for Fe and Mn. A Bodenmais specimen afforded Phosphorus pentoxide 44·19, iron protoxide 38·21, manganese protoxide 5·63, magnesia 2·39, lime 0·76, lithia 7·69, soda 0·74, potash 0·04, silica 0·40 = 100·05. B.B. fuses very easily, coloring the flame red, in streaks, with a pale bluish green on the exterior of the flame. Soluble in hydrochloric acid.

Obs. Found at Rabenstein in Bavaria; in Finland; at Norwich, Mass.; Grafton, N. H.

Lithiophilite. A salmon-colored manganese-lithium phosphate, allied in composition to triphylite, but containing very little iron. From Branchville, Ct.

Fairfieldite. Hydrous manganese-calcium phosphate; triclinic; white, yellowish; B.B. fuses with difficulty. From Branchville, Ct.; also Bavaria.

Leucomanganite. Snow-white, but contains manganese, iron, alkalies, and water. Rabenstein. Probably fairfieldite.

Triplite.

Orthorhombic; $I \wedge I = 120° 54'$. Usually massive; cleavage in three directions. Color blackish brown. Streak yellowish gray. Lustre resinous. Nearly or quite opaque. H. = 5–5·5. G. = 3·4–3·8.

Composition. $(Mn,Fe)_3O_8P_2 + RF_2$ (or $3(Mn,Fe)O + P_2O_5 + RF_2$), affording about 30 per cent. of manganese protoxide, 8 of fluorine. Fuses easily to a black magnetic globule. B.B. imparts a violet color to the hot borax bead. Dissolves in hydrochloric acid.

Obs. From Limoges in France; Washington, Ct.; Sterling, Mass.

Heterosite, Alluaudite, Pseudotriplite. Regarded as results of alteration, either of triphyline or of triplite.

Talktriplite is a triplite containing calcium and magnesium.

Triploidite. A manganese-iron phosphate, like triplite, but having the fluorine replaced by the elements of water. From Branchville, Ct.

Dickinsonite. Oil-green to olive-green; manganese-iron-calcium phosphate. From Branchville, Ct.

Reddingite. Rose-pink; hydrous manganese-iron phosphate. $Mn_3O_8P_2 + 3aq.$, isomorphous with scorodite. Branchville, Ct.

Hureaulite. Rose-colored to brownish orange; hydrous manganese-iron phosphate. Hureaux, France.

Fillowite. Manganese-iron-sodium phosphate; monoclinic; yellow, brown. From Branchville, Ct.

ARSENATES OF MANGANESE. *Allaktite, Diadelphite, Hemafibrite, Synadelphite, Polyarsenite, Sarkinite,* are names of arsenates. From weden.

CARBONATES.

Rhodochrosite.—Manganese Carbonate.

Rhombohedral; $R \wedge R = 106° 51'$; like calcite in having three easy cleavages, and in lustre. Color rose-red. H. = 3·5–4·5. G. = 3·4–3·7.

Composition. MnO_3C (or $MnO + CO_2$) = Carbonic acid 38·6, manganese protoxide 61·4 = 100. Part of the manganese often replaced by calcium, magnesium, or iron.

Obs. From Saxony, Transylvania, the Hartz, Ireland; Mine Hill, N. J.; Branchville, Ct.; Austin, Nev.; Alice Mine, Butte City, Montana; Summit Co., Col.; Placentia Bay, Newfoundland.

Rhodonite, Kentrolite, Helvite. Manganese silicates. See p. 268.

General Remarks.—The most productive localities of manganese ore in the United States are those of Augusta Co., Va., and Barton Co, Ga. The former produced, in 1885, 18,745 tons; the latter 2580; Arkansas about 1500, and other States about 500 tons. It is imported from Nova Scotia and Spain.

Manganese is never employed in the arts in the pure state. In the condition of ore, especially pyrolusite, it is largely employed in bleaching. The importance of the ore for this purpose depends on the oxygen it contains, and the facility with which this gas is given up. When this ore is treated with hydrochloric acid, the chlorine of the acid is given off; and by receiving this gas in slaked lime "bleaching powder" is made, a mixture of calcium chloride with calcium hypochlorite. The ore easily gives off its oxygen when highly heated, and its use in discharging the green and brown color of glass (due to iron) depends on this. The binoxide of manganese, when pure, affords 18 parts by weight of chlorine to 22 parts of the oxide; or 23½ cubic inches of gas from 22 grains of the oxide. The best ore should give about three-fourths its weight of chlorine, or about 7000 cubic inches to the pound avoirdupois.

Iron ores containing some manganese are used for making *spiegeleisen,* a hard highly crystallized pig-iron, containing 10 to 15 p. c. of manganese with a large amount of carbon. This spiegeleisen is commonly used in the Bessemer process for making steel. Manganese is also employed to give a violet color to glass. The sulphate and the chloride of manganese are used in calico printing. The sulphate gives a chocolate or bronze color. Manganese borate has been used to give the drying quality to varnishes.

ALUMINIUM.

The aluminium compounds among minerals include a sesquioxide AlO_3, hydrated oxides, fluorides, sulphates, phosphates, and numerous silicates. There are no sulphides or arsenides, and no carbonate, with a single exception.

The silicates are described in the following section. Many infusible aluminium compounds may be distinguished by means of a blowpipe experiment, as explained on page 98.

The metal aluminium is obtained by different methods from alumina, and the fluoride (cryolite); and recently, at Cleveland, from corundum easily by electric heating; reducing the price to five dollars a pound, or a third of the previous cost (Am. J. Sci. xxx., 308, 1885). It is highly useful in alloys with copper as aluminium bronze, and also with iron and other metals.

Oxides.

Corundum.

Rhombohedral; $R \wedge R = 86° 4'$. Cleavage sometimes perfect parallel to *O*, and sometimes parallel to *R*. Usual in six-sided prisms, often with uneven surfaces, and very irregular. Also granular massive. Colors: blue, and grayish blue most common; gray, red, yellow, brown, and nearly black; often bright. When polished on the surface *O*, an internal star of six rays sometimes distinct. Transparent to translucent. H. = 9, or next below the diamond. Exceedingly tough when compact. G. = 4 when pure; 3·94–4·16.

Composition. AlO_3 = Oxygen 46·8, aluminium 53·2 = 100; pure alumina. B.B. unaltered both alone and with soda. In fine powder with cobalt nitrate and ignited, becomes blue.

Varieties. The name *sapphire* is usually restricted, in common language, to clear crystals of bright colors, used as gems; while dull, dingy-colored crystals and masses are called *corundum*, and the granular variety of bluish gray and blackish colors containing much disseminated magnetite (whence its dark color) is called *emery*.

Blue is the true sapphire color. It is called *oriental ruby*, when red; *oriental topaz*, when yellow; *oriental emerald*, when green; *oriental amethyst*, when violet; and *adamantine spar*, when hair-brown. Crystals with a radiate chatoyant interior are very often beautiful, and are called *asteria*, or *asteriated sapphire*.

Diff. Distinguished readily by its great hardness.

Obs. The sapphire is often found loose in the soil. Metamorphic rocks, especially gneissoid mica schist, and granular limestone, appear to be its usual matrix. It is met with in several localities in the United States; blue at Newton, N. J., crystals sometimes several inches long, also at Franklin and Sparta; bluish and pink crystals at Warwick, and white, blue, and reddish at Amity, N. Y.; grayish, in large crystals, in Delaware and Chester Cos., Pa.; pale blue in bowlders at West Farms and Litchfield, Ct. Abundant at Corundum Hill, Macon Co., N. C., where crystals are numerous, and some fit for jewelry, and where one has been obtained weighing 312 pounds, having a reddish color outside and a bluish-gray within; also in Jackson, Burke, Heywood, Madison, and Clay, and other Cos.; Laurens Dist., S. C.; Tallapoosa Co., Ala.; also in Fannin Co., Ga.; Los Angeles Co., Cal.; near Helena, Montana, affording some good gems; Santa Fé, N. Mexico; Arizona; Colorado; emery, formerly mined, at Chester, Mass.

The principal foreign localities are as follows: blue, from Ceylon; the finest red from the Capelan Mountains in the kingdom of Ava, and smaller crystals from Saxony, Bohemia, and Auvergne; corundum, from the Carnatic, on the Malabar coast, and elsewhere in the East Indies; adamantine spar, from the Malabar coast; emery, in large bowlders, from near Smyrna, and also at Naxos and several of the Grecian islands.

The name sapphire is from the Greek word *sappheiros*, the name of a blue gem. It is doubted whether it included the sapphire of the present day.

Next to the diamond, the sapphire in some of its varieties is the most costly of gems. The red sapphire is much more highly esteemed than those of other colors; a crystal of one, two, or three carats has the value of a diamond of the same size. They seldom exceed half an inch in their dimensions. Two splendid red crystals, as long as the little finger and about an inch in diameter, are said to be in the possession

of the king of Arracan. The largest oriental ruby known was brought from China to Prince Gargarin, governor of Siberia; it afterwards came into the possession of Prince Menzikoff, and constitutes now a jewel in the imperial crown of Russia. Blue sapphires occur of much larger size. According to Allan, Sir Abram Hume possessed a crystal which was three inches long. One of 9·51 carats is stated to have been found in Ava.

Corundum and emery are crushed to a powder of different degrees of fineness, and make the abrading and polishing material called in the shops *emery*. The iron oxide of true emery diminishes its hardness, and consequently its abrasive power; pulverized corundum is more valuable and efficient in abrasion.

Diaspore. Aluminium hydrate, AlO_4H_3 (or $Al_2O_3H_2O$) = Water 14·9, alumina 85·1 = 100; crystals usually thin plates; also acicular; whitish, grayish, pinkish, etc.; brittle; translucent; H. 6·5–7; G. 3·5. The Urals; Schemnitz; Chester, Mass.; Unionville, Chester Co., Pa., some cryst. 1½ in. long; Culsagee mine, N. C. Usually found with corundum.

Gibbsite (*Hydrargillite*). Aluminium hydrate; AlO_6H_6 = Water 34·5, alumina 65·5 = 100. In hexagonal crystals, sometimes transparent; commonly in whitish stalactitic and mammillary forms, with smooth surface, looking like chalcedony; H. = 2·5–3·5; G. = 2·3–2·4. Near Slatoust in the Ural; Asia Minor; on corundum at Unionville, Pa.; at Richmond, Mass., stalactitic; in Dutchess and Orange Cos., N. Y. *Zirlite* is similar.

Hydrotalcite (*Völknerite, Houghite*). Soft pearly; contains alumina, magnesia, and water. A result of the alteration of spinel crystals. Near Slatoust; Snarum, Norway; Oxbow, Rossie, St. Lawrence Co., N. Y. (var. *Houghite*).

Beauxite. Aluminium-iron hydrate; in concretionary forms and grains. Beaux, France, etc.

Spinel.

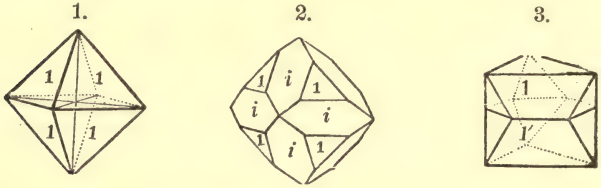
Isometric. In octahedrons, more or less modified. Figure 3 represents a twin crystal. Occurs only in crystals; cleavage octahedral, but difficult.

Color red, passing into blue, green, yellow, brown, and black. The red shades often transparent and bright; the dark shades usually opaque. Lustre vitreous. H. = 8. G. = 3·5–4·1.

Composition. $MgAlO_4$ (or $MgO + AlO_3$) = Alumina 72, magnesia 28 = 100. The aluminium is sometimes replaced in part by iron, and the magnesium often in part by

iron, calcium, manganese, and zinc. Infusible; insoluble in acids.

VARIETIES. The scarlet or bright red crystals, *spinel ruby;* rose-red, *balas-ruby;* orange-red, *rubicelle;* violet, *almandine ruby;* green, *chloro-spinel;* black, *pleonaste.*



Pleonaste contains sometimes 8 to 20 per cent. of oxide of iron. *Picotite* contains iron with 7 p. c. of chromium oxide; G. = 4·08.

Diff. The form of the crystals and their hardness distinguish the species. Garnet is fusible. Magnetite is attracted by the magnet. Zircon has a higher specific gravity. The red crystals often resemble the true ruby (red corundum), but the latter are never in octahedrons.

Obs. Occurs in granular limestone; also in gneiss and volcanic rocks. At numerous places in the adjoining counties of Sussex, N. J., and Orange Co., N. Y., of various colors from red to brown and black; especially at Vernon, Franklin, Newton, and Hamburg, in the former, and in Warwick, Amity, Monroe, Norwich, Cornwall, and Edenville in the latter. One octahedron, found at Amity by Dr. Heron, weighed 49 pounds. The limestone quarries of Bolton, Boxborough, Chelmsford, and Littleton, Mass., afford a few crystals; also San Luis Obispo, Cal.; bluish, at Wakefield, Canada.

Crystals of spinel have occasionally undergone a change to the steatite-like mineral *hydrotalcite* (see p. 213).

Uses. The fine colored spinels are much used as gems. The red is the common ruby of jewelry, the *oriental* rubies being sapphire.

Gahnite. A spinel in which zinc takes the place of part or all of the magnesium; when all, it is called *Automolite;* dark green or greenish black; H. = 7·5–8; G. = 4–4·6; fused with sufficient soda, B.B. on coal, a white coat of zinc oxide, which is yellow when hot; B.B. infusible. Franklin, N. J.; Rowe, Mass., in a vein of pyrite;

Mitchell Co., Deak mine, N. C.; Canton mine, Ga.; Colorado; New Mexico; Sweden, near Fahlun, in talcose slate.

Dysluite. A gahnite containing manganese; yellowish or grayish brown; H. = 7·5–8; G. = 4·55; composition, Alumina 30·5, zinc oxide 16·8, iron sesquioxide 41·9, manganese protoxide 7·6, silica 3, water 0·4. Sterling, N. J., with franklinite and troostite.

Kreittonite. A zinc-iron gahnite; G. = 4·48–4·89.

Hercynite. A spinel affording on analysis alumina and iron protoxide, with only 2·9 per cent. of magnesia; G. = 3·9–3·95.

Chrysoberyl.

Orthorhombic; $I \wedge I = 129° 38'$. Also in compound crystals, as in Fig. 2. Crystals sometimes thick; often tabular.

Color bright green, from light to emerald-green and brown; rarely raspberry- or columbine-red by transmitted light. Streak uncolored. Lustre vitreous. Transparent to translucent. H. = 8·5. G. = 3·7–3·86.

Composition. $BeAlO_2$ (or $BeOAlO_3$) = Alumina 80·2, glucina 19·8 = 100. B.B. infusible and unaltered.

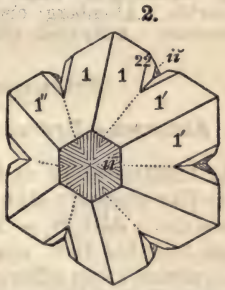
Alexandrite, from the Urals, is colored emerald-green by chrome; bears the same relation to ordinary chrysoberyl as emerald to beryl. Fig. 2 is of this variety.

Diff. Near beryl, but distinct in not being regularly hexagonal in crystallization.

Obs. Chrysoberyl occurs in the United States in granite at Haddam, Ct. (loc. not accessible); Greenfield, near Saratoga, N. Y.; Stow (one crystal 3 × 5 × 1 inches), Canton, Peru, Stoneham, Norway, Maine.

1.

2.



Named from the Greek *chrysos,* golden, *beryllos,* beryl.

The crystals are seldom sufficiently pellucid and clear from flaws to be valued in jewelry; but when of fine quality, it forms a beautiful gem, and is often opalescent.

Fluorides of Aluminium.

Cryolite.—Aluminium-Sodium Fluoride. Ice Stone.

Monoclinic; $I \wedge I = 88\frac{1}{2}°–88°$. Rectangular cleavages. Usually massive; white. Translucent. G. = 2·9–3·1.

Composition. $3NaF + AlF_3$ = Aluminium 13·0, sodium 32·8, fluorine 54·2 = 100. Fusible in the flame of a candle, and thus easily distinguished.

Obs. From Greenland; sparingly, Pike's Peak region, at the N. E. base of St. Peter's Dome. Used in making soda, porcelain-like glass, and the metal aluminium. Another cryolite-like species, *Elpasolite*, occurs at Pike's Peak, in which the sodium is largely replaced by potassium.

Pachnolite. Monoclinic; $I \wedge I = 81° 24'$; white, yellowish; like cryolite in composition except that half the sodium is replaced by calcium, and water is present; formed by the alteration of cryolite. Greenland; Pike's Peak, Col.

Thomsenolite. Like pachnolite in composition; monoclinic; $I \wedge I$ near 90°; cleavage basal, very perfect; Greenland; Pike's Peak.

Gearksuktite. Earthy, kaolin-like; hydrous, like the last, but containing calcium with no sodium. Greenland; Pike's Peak. *Evigtokite* is probably the same.

Arksuktite, Chiolite, Chodneffite are related species, the latter two from Siberia.

Ralstonite. In minute cubo-octahedrons; a hydrous sodium-aluminium fluoride. Occurs in Greenland cryolite; probably with pachnolite of Pike's Peak.

Fluellite. In minute white rhombic octahedrons; contains aluminium and fluorine. Cornwall.

Prosopite. Monoclinic; white or grayish; a hydrous aluminium-calcium fluoride. Altenberg; cryolite locality of Pike's Peak.

Chloraluminite. A hydrous aluminium chloride. Vesuvius.

Sulphates, Borates.

Alunogen.—Hydrous Aluminium Sulphate.

In silky efflorescences and crusts of a white color, having a taste like common alum. H. = 1·5–2. G. = 1·6–1·8.

Composition. $Al_2O_{12}S_3 + 18aq.$ (or $Al_2O_3 + 3SO_3 + 18aq.$) = Sulphur trioxide 36·0, alumina 15·4, water 48·6 = 100.

Obs. Common as an efflorescence in solfataras of volcanic regions, and also often occurring in shales of coal regions and other rocks containing pyrite; the oxidation of the iron sulphide affords sulphuric acid, which acid combines with the alumina of the shale.

Alums. Frequently the sulphuric acid resulting from the oxidation of a sulphide, or in some other way, combines also with the iron, magnesia or potash or soda of the shale or other rock, as well as the alumina, and so makes other kinds of aluminium sulphate.

Combining thus with potash, it produces common alum called *Kalinite* or *potash alum*, whose formula is $K_2Al_2O_{24}S_4 + 18aq.$; with ammonia, it forms an *ammonia-alum*, named *Tschermigite;* with iron, iron-alum, called *Halotrichite;* with soda, soda-alum, *Mendozite;* with magnesia, magnesia-alum, *Pickeringite;* with manganese, manganese alum, *Apjohnite* and *Bosjemanite.* The formulas of these alums are alike in atomic proportions, excepting in the amount of water, which varies from 18aq. to 24aq.

Sonomaite. From the Geyser region of Sonoma Co., Cal., is near pickeringite. *Plagiocitrite* is soluble aluminium-sodium-potassium-iron sulphate. *Lœwigite* is aluminium-potassium sulphate, containing half the water of pickeringite. *Dumreicherite* is a magnesian alum of peculiar composition. *Dietrichite* is near the alums.

Shale containing alunogen or any of the alums is often called *alum shale.* Rocks, whether shales or of other kinds, are often quarried and lixiviated for the alum they contain or will afford. The rock is first slowly heated after piling it in heaps, in order to decompose the remaining pyrites and transfer the sulphuric acid of any iron sulphate to the alumina and thus produce the largest amount possible of aluminium sulphate. It is next lixiviated in stone cisterns. The lye containing this sulphate is afterwards concentrated by evaporation, and then the requisite proportion of potassium in the form of the sulphate or chloride is added to the hot solution. On cooling, the alum crystallizes out, and is then washed and recrystallized. The mother liquor left after the precipitation is revaporated to obtain the remaining alum held in solution. This process is carried on extensively in Germany, France, at Whitby in Yorkshire, Hurlett and Campsie, near Glasgow, in Scotland. Cape Sable in Maryland affords large quantities of alum annually. The slates of coal beds are often used to advantage in this manufacture, owing to the decomposing pyrites present. At Whitby, 130 tons of calcined schist give one ton of alum. In France, ammoniacal salts are used instead of potash, and an ammonia alum is formed.

Alunite.—Alum Stone.

Rhombohedral, with perfect basal cleavage. Also massive. Color white, grayish, or reddish. Lustre of crystals vitreous, or a little pearly on the basal plane. Transparent to translucent. H. = 4. G. = 2·58–2·75.

Composition. $K_2AlO_{22}S_4 + 6aq.$ (or $K_2OSO_3 + 3AlO_3SO_3 + 6aq.$) = Sulphur trioxide 38·5, alumina 37·1, potash 11·4, water 13·0 = 100. B.B. decrepitates, infusible; reaction for sulphur.

Diff. Distinguished by its infusibility, and its complete solubility in sulphuric acid without forming a jelly.

Obs. Found in rocks of volcanic origin at Tolfa, near Rome; and also at Beregh and elsewhere in Hungary.

When calcined, the sulphates become soluble, and the alum is dissolved out. On evaporation the alum crystallizes from the fluid in cubic crystals. This is called Roman alum, and is highly valued by dyers, because, although the crystals are colored red by iron oxide, no iron is chemically combined with the salt, as is usual in common alum.

Aluminite (*Websterite*). Another hydrous aluminium sulphate, in compact reniform masses, and tasteless. From New Haven, in Sussex; Epernay, in France; and Halle, in Prussia. *Werthemanite* is a related mineral containing less water, from Chili; and *Picrallumogen* another, containing about 8 p. c. of magnesia.

Jeremejeffite. Aluminium borate; in hexagonal crystals. W. Siberia.

Phosphates.

Amblygonite.—Lithium-Aluminium Phosphate.

Triclinic, with cleavages unequal in two directions, inclined to one another $104\frac{1}{2}°$. Lustre vitreous to pearly and greasy. Color pale mountain-green or sea-green to white. Translucent to subtransparent. H. = 6. G. = 3–3·11.

Composition. A lithium-aluminium phosphate, $AlO_6P_2 + (LiNa)_2(FOH)$, (or $Al_2O_3 + P_2O_5 + [Li_2Na_2]\,[FOH]$). B.B. fuses very easily with intumescence, coloring the flame yellowish red to rich carmine-red, owing to the lithia present, with traces of green owing to the phosphoric acid; reaction also for fluorine.

Obs. Occurs in Saxony and Norway; at Montebras (*Montebrasite*), France; Hebron and Mount Mica (*Hebronite*) in Maine; Branchville, Ct.

Durangite. Anhydrous aluminium arsenate, containing aluminium, sodium, iron, and some manganese, with over 7 per cent. of fluorine; monoclinic; orange-red; G. = 3·9–4·1. Barranca tin-mine, Durango, Mexico, with cassiterite or tin ore.

Lazulite.

Monoclinic. In crystals; also massive. Color azure-blue. H. = 5–6. G. = 3·057.

Composition. $RAlO_9P_2 + aq$ = Phosphorus pentoxide 46·8, alumina 34·0, magnesia 13·2, water 6·0 = 100. B.B. in the closed tube whitens, yields water; with cobalt solution the color is restored; in the forceps whitens, swells, falls to pieces without fusion, coloring the flame bluish green.

Obs. From Salzburg, Styria; Wermland, Sweden; Crowder Mount, Lincoln Co., N. C.; Graves Mountain, Lincoln Co., Ga.; Keewatin Dist., Canada.

Variscite (*Peganite, Callainite*). A hydrous aluminium phosphate; color light green, of various shades, to deep emerald-green. From Montgomery Co., Ark.; Colorado; Messbach, in Saxon Voigtland. *Fischerite* is a related mineral.

Evansite. Hydrous aluminium phosphate; looks like allophane. Hungary.

Goyazite. Hydrous aluminium-calcium phosphate; yellowish-white Minas Geraes, Brazil.

Turquois.

Massive, reniform, without cleavage. Color bluish green. Lustre somewhat waxy. H.=6. G.=2·6–2·8.

Composition. Phosphorus pentoxide 22·6, alumina 46·9, water 20·5=100. B.B. infusible, but becomes brown; colors the flame green. Soluble in hydrochloric acid; moistened with the acid, gives a momentary bluish green color to the flame, owing to the copper present.

Diff. Distinguished from bluish green feldspar, which it resembles, by its infusibility and the reactions for phosphorus.

Obs. Found in a mountainous district in Persia, not far from Nichabour; N. Mexico, in Los Cerillos, at Mt. Chalchuitl, 22 m. from Santa Fé; in Turquois Mtn., Arizona; in S. Nevada, 5 m. N. of Columbus.

The *Callais* of Pliny was probably turquois. Pliny, in his description of it, mentions the fable that it was found in Asia, projecting from the surface of inaccessible rocks, whence it was obtained by means of slings.

Receives a fine polish and is highly esteemed as a gem. The Persian king is said to retain for himself all the large and more finely-tinted specimens. The New Mexico locality affords fine gems. Prof. W. P. Blake regards the turquois as resulting from the decomposition of a trachyte. The *occidental* or *bone* turquois is fossil teeth or bones, colored with a little phosphate of iron. Green *malachite* is sometimes substituted for turquois; but it is softer, and different in color. The stone is so well imitated by art as scarcely to be detected except by chemical tests; but the imitation is much softer than true turquois.

Childrenite. Orthorhombic; yellow to brown; hydrous phosphate,

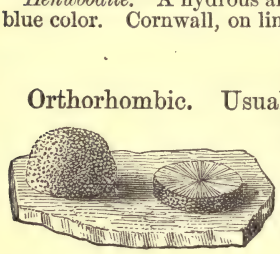
containing aluminium, iron, with little manganese. In crystals in Devonshire and Cornwall; Hebron, Me.

Eosphorite. Has the crystalline form of childrenite, and contains the same constituents, but differs in being essentially a hydrous phosphate of manganese with *little iron;* rose-red; G.=3·1–3·5. Branchville, Connecticut.

Henwoodite. A hydrous aluminium-copper phosphate, of turquois blue color. Cornwall, on limonite.

Wavellite.

Orthorhombic. Usually in small hemispheres a third or half an inch across, finely radiated within; when broken off they leave a stellate circle on the rock. Sometimes in rhombic crystals; also stalactitic.



Color white, green, or yellowish and brownish, with a somewhat pearly or resinous lustre. Sometimes gray or black. Translucent. H.=3·5–4. G.=2·3–2·34.

Composition. $Al_3O_{12}P_4+12$ aq (or $3AlO_3+2P_2O_5+12$ aq) = Phosphorus pentoxide 35·16, alumina 38·10, water 26·74 = 100. 1 to 2 per cent. of fluorine often present, replacing oxygen. B.B. whitens, swells, but does not fuse. Colors the flame green, especially if moistened with sulphuric acid; moistened with cobalt nitrate, becomes blue after ignition; gives much water in the closed glass tube.

Diff. Distinguished from the zeolites, some of which it resembles, by giving the reaction of phosphorus, and also by dissolving in acids without gelatinizing. Cacoxene, to which it is allied, becomes dark reddish brown B.B., and does not give the blue with cobalt nitrate.

Obs. Slate quarries of York Co., Pa.; Washington Mine, Davidson Co., N. C.; Magnet Cove, Ark. First discovered by Dr. Wavel in clay slate in Devonshire. Also in Bohemia and Bavaria.

Zepharovichite is near wavellite.

Liskeardite. A hydrous aluminium arsenate; incrusting; white, bluish. Cornwall.

Mellite or *Honey stone.* In square octahedrons; honey-yellow; an aluminium mellate. Thuringia, Bohemia, Moravia, etc.

Aluminium Carbonate.—Dawsonite. Hydrous aluminium-sodium carbonate, an analysis afforded Carbon dioxide 27·78, alumina 36·12, soda 22·86, water 13·24 = 100. From a felsyte dike near Montreal; Siena, Tuscany.

CERIUM, YTTRIUM, ERBIUM, LANTHANUM, DIDYMIUM.

Known in nature in the condition of fluorides, tantalates, columbates, phosphates, or carbonates, and also as constituents in several silicates.

Yttrocerite.

Massive. Color violet-blue (somewhat resembling purple fluorite); also reddish brown. Lustre glistening. Opaque. H. = 4–5. G. = 3·4–3·5.

Composition. Fluorine 25·1, lime 47·6, cerium protoxide 18·2, yttria 9·1. B.B. alone infusible.

Obs. From Finbo and Broddbo, Sweden; Mt. Mica, Me.; probably Worcester Co., Mass.; Amity, Orange Co., N. Y.

Tysonite. Fluoride of cerium, lanthanum, and didymium, in wax-yellow, hexagonal crystals. Pike's Peak, Col.

Fluocerite, Fluocerine. Other fluorides containing cerium. Sweden.

Samarskite.

Orthorhombic; $I \wedge I = 122° 46'$. Usually massive, without cleavage. Color velvet-black. Lustre shining submetallic. Streak dark reddish brown. Opaque. H. = 5·5–6. G. = 5·6–5·8.

Composition. Analyses of the American afford niobic and tantalic pentoxide, with sesquioxides of yttrium (12–15 per cent.), cerium, didymium, and lanthanum, iron, and oxide of uranium. The new metals terbium, decipium, phillipium have been reported from the samarskite. In the closed tube decrepitates and glows. B.B. fuses on the edges to a black glass. With salt of phosphorus in both flames, an emerald-green bead.

Obs. At Miask, in the Ural; in masses, sometimes weighing many pounds, at the Mica mines of Western N. Carolina, along with columbite; rare at Middletown, Ct.

Nohlite and *Vietinghofite* are near samarskite.

Fergusonite. Hydrous niobate of yttrium, erbium, cerium; brownish black; lustre brilliantly vitreous on a surface of fracture; B.B. infusible, but loses its color. Sweden; Cape Farewell, Greenland; Rockport, Mass.; Burke and Mitchell cos., N. C.

Kochelite. Near fergusonite. Silesia.

Annerödite. Orthorhombic; black, metallic or submetallic; niobate of uranium, yttrium, thorium, cerium, etc. Anneröd, Norway.

Yttro-tantalite. A tantalate and niobate of yttrium, erbium and iron; different varieties are the black, the yellow, and the brown or

dark-colored; infusible. Ytterby, Sweden; Broddbo and Finbo, near Fahlun.

Euxenite. A niobate and tantalate of yttrium, uranium, erbium, and cerium; massive; brownish black; streak reddish brown; B.B. infusible. Norway.

Sipylite. A niobate and tantalate of erbium and yttrium, resembling fergusonite in aspect; stated to contain also phillipium and ytterbium. Amherst Co., Va.

Æschynite. Black to brownish yellow; resinous to submetallic; H. = 5–6; G. = 4·9–5·1; a niobate and titanate of cerium, thorium, lanthanum, didymium, and erbium. Miask, Urals; Norway.

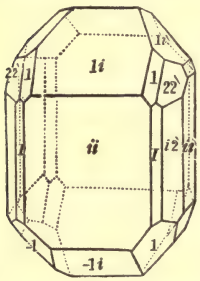
Polymignite and *Polycrase.* Related to æschynite. Norway.

Pyrochlore, Microlite, Disanalyte, under CALCIUM, p. 234.

Rogersite. A hydrous yttrium niobate; in whitish crusts, on samarskite. From Mitchell Co., N. C.

Monazite.

Monoclinic; $I \wedge I = 93° 10'$, $C = 76° 14'$. Perfect and brilliant basal cleavage. Observed only in imbedded crystals.



Color brown, brownish red; subtransparent to nearly opaque. Lustre vitreous inclining to resinous. Brittle. H. = 5. G. = 4·8–5·1.

Composition. A phosphate of cerium, lanthanum, yttrium, and didymium. B.B. colors the flame green when moistened with sulphuric acid and heated. Difficultly soluble in acids.

Diff. The brilliant easy transverse cleavage distinguishes monazite from sphene.

Obs. Occurs near Slatoust, Russia; at Tavetsch and Binnenthal, Switzerland (*Turnerite*); in the U. States in small brown crystals, disseminated through a mica schist at Norwich and Chester, Ct.; also at Portland, Ct.; Yorktown, Westchester Co., N. Y.; Alexander Co., and elsewhere, N. C.; Amelia Co., Va., in masses of 8 pounds and less.

Cryptolite. A cerium phosphate; in minute yellow six-sided prisms in apatite. Arendal, Norway.

Churchite. Phosphate of cerium, didymium, and calcium. Cornwall.

Xenotime. Yttrium phosphate; tetragonal, lateral cleavage perfect; yellowish brown; opaque; lustre resinous; H. = 4–5; G. = 4·6; B.B. infusible. Lindesnaes, Norway; Ytterby, Sweden; gold-washings of Clarkesville, Ga.; McDowell and Alexander Cos., N. C.; near Pike's Peak, Col.

Bastnäsite. A carbonate of cerium, lanthanum, and didymium, containing fluorine. Bastnäs, Sweden; Pike's Peak, Col.

Rhabdophane (*Scovillite*). Hydrous phosphate of cerium, lanthanum, and didymium; in pink and brownish incrustations on manganese ore. Salisbury, Ct. *Phosphocerite* is the same.

Rutherfordite. Blackish brown; vitreo-resinous. Rutherford Co., N. C.

CARBONATES.—*Parisite.* A carbonate containing cerium, lanthanum, and didymium, with fluorine. New Granada.

Lanthanite. Hydrous lanthanum carbonate; in thin minute tables or scales; whitish or yellowish. Bastnäs, Sweden; Saucon Valley, Lehigh Co., Pa.

Tengerite. Yttrium carbonate; in thin coatings. Ytterby.

Allanite, Gadolinite, Keilhauite, Tscheffkinite, and *Erdmannite* are silicates containing either cerium or yttrium.

MAGNESIUM.

Magnesium occurs, in nature, as an oxide and a hydrated oxide, and in the condition of sulphate, borate, nitrate, phosphate, carbonate, and silicate.

The sulphates and nitrate of magnesia are soluble in water, and are distinguished by their bitter taste; the other native magnesian salts are insoluble. The presence of magnesia in infusible species, when no metallic oxides are present, is indicated by a blowpipe experiment explained on page 98.

Periclasite.—Periclase. Magnesium Oxide.

Isometric. In small imbedded crystals, with cubic cleavage. Color grayish to dark green. H. nearly 6. G. = 3·674.

Composition. MgO (or the same as for *magnesia alba* of the shops), with a little iron as impurity. B.B. infusible. Soluble in acids without effervescence.

From Mount Somma, Vesuvius, Italy.

Sellaite. Tetragonal; colorless; transparent; fuses in a candle; magnesium fluoride (MgFl). Geibroula, Piedmont.

Brucite.—Magnesium Hydrate.

Rhombohedral. In hexagonal prisms and plates; thin foliated, the thin laminæ easily separated; also fibrous, resembling amianthus (*Nemalite*). Translucent. Flexible but not elastic. Lustre pearly. Color white, often grayish or greenish. H. = 2·5. G. = 2·35–2·45.

Composition. MgO_2H_2 (or $MgO + H_2O$) = Magnesia 69·0,

water 31·0 = 100. B.B. infusible, but becomes opaque and alkaline. Soluble in hydrochloric acid without effervescence. *Manganbrucite* is a manganesian variety.

Diff. Resembles talc and gypsum, but is soluble in acids; differs from heulandite and stilbite also by its infusibility.

Obs. Occurs in serpentine at Hoboken, N. J.; Staten Island, and Brewster's, N. Y.; at Texas, Pa.; Swinaness, in Unst, one of the Shetland Isles.

Pyroaurite (*Igleströmite*). Magnesium-iron hydrate, silvery white to golden. Longban, Wermland; Scotland.

Hydromagnesite. White pearly crystalline, or earthy, hydrous carbonate of magnesia. Hoboken, N. J.; Texas, Pa.; and elsewhere.

Spinel contains oxygen and magnesium along with aluminium. See page 213. Magnesium is also present in some magnetite, a variety of which is called *Magneferrite.*

Nocerine. A magnesium calcium fluoride: from Nocera tufa.

Chlormagnesite. Magnesium chloride from Vesuvius. *Bischofite,* from a salt mine in Prussia, is probably the same.

Carnallite. Hydrous magnesium-potassium chloride. Stassfurth.

Tachhydrite. Hydrous magnesium-calcium chloride. Stassfurth.

Epsomite.—Epsom Salt. Magnesium Sulphate.

Orthorhombic; $I \wedge I = 90° 34'$. Cleavage perfect, parallel with the shorter diagonal. Usually in fibrous crusts or botryoidal masses. Color white. Lustre vitreous to earthy. Very soluble; taste saline bitter.

Composition. $MgO,S + 7\,aq$ (or $MgO + SO_3 = 7\,aq$) = Sulphur trioxide 32·5, magnesia 16·3, water 51·2 = 100. Liquefies in its water of crystallization when heated. Gives much water, acid in reaction, in the closed tube.

Diff. The fine spicula-like crystalline grains of Epsom salt, as it appears in the shops, distinguish it from Glauber salt, which occurs usually in thick crystals.

Obs. Occurs as an efflorescence in the galleries of mines and elsewhere. Sometimes in minute crystals mingled with the earth of the floors of caves. In the Mammoth Cave, Ky., it adheres to the roof in loose masses like snowballs. The fine efflorescences suggested the old name *hair-salt.*

Occurs dissolved in mineral springs at Epsom, in Surrey, England, and thence the name it bears; at Sedlitz, Aragon; in a grotto in Southern Africa, a layer an inch and a half thick; massive (*Reichardtite*) at Stassfurth.

Its medical uses are well known. It is obtained for the

arts from the bittern of sea-salt works, but now chiefly from dolomite or magnesite, by decomposing with sulphuric acid.

Polyhalite. Hydrous calcium-magnesium sulphate; massive, somewhat fibrous in appearance; brick-red; taste weak. Bitter. Ischl and other salt-mines. *Krugite* is similar.

Kieserite. Hydrous magnesium sulphate. Stassfurth.

Picromerite. Hydrous potassium-magnesium sulphate; white. Stassfurth. *Kainite*, sulphato-chloride of same bases.

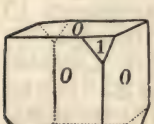
Blœdite. A hydrous sodium-magnesium sulphate. Salt-mines of Ischl; near Mendoza. *Simonyite* is related; from Hallstadt.

Lœweite. A hydrous sodium-magnesium sulphate; contains more sulphur trioxide than Blœdite. Ischl.

Boracite.—Magnesium Borate.

Isometric. Usual in small cubes; with the alternate angles replaced, or with all replaced but four of them differently from the other four. Cleavage only in traces. Also massive. In crystals, translucent. Color white or grayish; yellowish or greenish. Lustre vitreous. H. of crystals = 7; when massive, softer. G. = 2·97. Becomes electric when heated, with the opposite angles of the cube of opposite polarity.

1.



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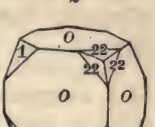


Composition. $Mg_3O_{15}B_8 + \frac{1}{2}MgCl_2$ (or $3MgO + 4B_2O_3 + \frac{1}{2}MgCl_2$) = Boron trioxide 62·0, magnesia 31·0, chlorine 7·0 = 100. B.B. fuses easily with intumescence, coloring the flame green; globule crystalline on cooling. Dissolves in hydrochloric acid; wet with cobalt nitrate turns pink on ignition.

Diff. Distinguished readily by its form, high hardness, and pyro-electric properties.

Obs. With gypsum and common salt, near Lüneburg in Saxony; near Kiel, Prussia; also at Stassfurth.

Rhodizite. Like boracite in its crystals, but tinges the blowpipe flame deep red; supposed to be a lime-boracite. With red tourmaline in Siberia.

Ludwigite. A magnesium-iron borate; fibrous; dark green to black.

Szaibelyite. A hydrous magnesium borate. Hungary. *Pinnoite* is another; Stassfurth.

Warwickite. In rhombic prisms of 93° to 94°; hair-brown to black

with sometimes a copper-red tinge; a magnesium-titanium borate. Edenville, N. Y., in crystalline limestone.

Sussexite. A hydrous magnesium-manganese borate; fibrous and pearly; G. = 3·42. Mine Hill, Franklin Furnace, Sussex Co., N. J.

Nitromagnesite. Magnesium nitrate; in white deliquescent efflorescences, having a bitter taste. With calcium nitrate, in limestone caverns. Used, like its associate, in the manufacture of saltpetre.

Wagnerite. A magnesium fluo-phosphate; yellowish or grayish oblique rhombic prisms; insoluble; H. = 5–5·5; G. = 3·1. Salzburg, Austria. *Kjerulfine* is wagnerite.

Newberyite. Orthorhombic tabular crystals, from guano; hydrous magnesium phosphate. Skipton Caves, Victoria.

Hœrnisite and *Rœsslerite.* White hydrous magnesium arsenates.

Lüneburgite. A magnesium boro-phosphate. Lüneburg.

Magnesite.—Magnesium Carbonate.

Rhombohedral; $R : R = 107° 29'$. Cleavage rhombohedral, perfect. Often massive, either granular, or compact and porcelain-like, in tuberose forms; also fibrous.

Color white, yellowish or grayish white, brown. Lustre vitreous; fibrous varieties often silky. Transparent to opaque. H. = 3–4·5 G. = 3; 3–3·2 when ferriferous.

Composition. MgO_3C (or $MgO + CO_2$) = Carbon dioxide 52·4, magnesia 47·6 = 100. B.B. infusible; after ignition, an alkaline reaction; nearly insoluble in cold dilute hydrochloric acid, but dissolves with effervescence in hot.

Diff. Resembles some calcite and dolomite; but from a concentrated solution no calcium sulphate is precipitated on adding sulphuric acid. The fibrous variety is distinguished from most other fibrous minerals by effervescence in hot acid, which shows it to be a carbonate.

Breunnerite is a magnesite containing iron; turns brown on exposure.

Obs. Usually associated with magnesian rocks, especially serpentine. At Hoboken, N. J., in fibrous seams; similarly at Lynnfield, Mass.; Texas, Pa.; Bare Hills, Md.; in Canada, at Bolton, massive and imperfectly fibrous, traversing white limestone.

A convenient material for the manufacture of magnesium sulphate or Epsom salt, to make which requires simply treatment with sulphuric acid, and so used on a large scale in Maryland and Pennsylvania.

Hydromagnesite. A hydrous magnesium carbonate; contains about 20 p. c. of water. With serpentine. Hoboken, N. J.; Texas, Pa.

Hydrogiobertite is similar, but gave 29·93 p. c. of water and less CO_2. From Pollenza, Italy.

CALCIUM.

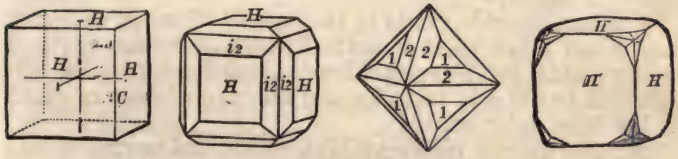
Calcium exists in nature in the state of fluorite, and this is its only native binary compound. It occurs in ternaries in the state of sulphate, borate, columbate, phosphate, arsenate, carbonate, titanate, oxalate, and silicate. The carbonate (calcite and limestone) is one of the three most abundant of minerals. The fluoride and sulphate, and some silicates, are also of very common occurrence.

With the exception of the calcium nitrate, none of the native salts of lime are soluble in water except in small proportions. Before the blowpipe they give no odor, and no metallic reaction; but they tinge the flame red; and many of them give up a part of their acid constituent, and become caustic and react alkaline. The specific gravity is below 3·2, and hardness not above 5.

Fluorite.—Fluor Spar. Calcium Fluoride.

Isometric; Figs. 1 to 4. Cubes most common. Cleavage octahedral, perfect. Rarely fibrous; often compact, coarse, or fine granular.

1. 2. 3. 4.



Colors usually bright; white, or some shade of light green, purple, or clear yellow most common; rarely rose-red and sky-blue; colors of massive varieties often banded. Transparent, translucent, or subtranslucent. H. = 4. G. = 3–3·25. Brittle.

Composition. CaF_2 = Fluorine 48·7, calcium 51·3 = 100. Phosphoresces when gently heated (as seen in the dark), affording light of different colors, as emerald-green, purple, blue, rose-red, pink, orange. B.B. decrepitates, and ultimately fuses to an enamel, having an alkaline reaction; treated in powder with sulphuric acid, hydrofluoric acid gas is given off which corrodes glass. *Chlorophane* is the kind affording a bright green phosphorescence.

Diff. In its bright colors, fluorite resembles some of the gems, but its softness and its easy octahedral cleavage when crystallized at once distinguish it. Its strong phosphorescence is a striking characteristic; and also its affording easily, with sulphuric acid and heat, a gas that corrodes glass.

Obs. Fluorite occurs in gneiss, mica schist, clay slate, limestone, and sparingly in beds of coal either in veins or occupying cavities, or as imbedded masses. It is the gangue in some lead-mines.

Cubic crystals of a greenish color, over a foot each way, have been obtained at Muscolonge Lake, St. Lawrence County, N. Y.; near Shawneetown on the Ohio, a beautiful purple fluor in grouped cubes of large size is obtained from limestone and the soil of the region; at Westmoreland, N. H., at the Notch in the White Mountains; Blue Hill Bay, Maine; Putney, Vt.; Lockport, N. Y.; Boulder Co., Cal.; Crystal Park, El Paso Co., Col.; Montana; Wyoming; N. Mexico; Pike's Peak, Col. *Chlorophane* var. at Trumbull, Ct., and Amelia Court House, Va.

In Derbyshire, England, abundant, and hence the name *Derbyshire spar*. A common mineral in the mining districts of Saxony.

Calcium fluoride exists in the enamel of teeth, in bones, and some other parts of animals; also in certain parts of many plants; and by vegetable or animal decomposition it is afforded to the soil, to rocks, and also to coal-beds in which it has been detected.

Massive fluorite receives a high polish, and is worked into vases and various ornaments in Derbyshire, England. Some of the varieties from this locality, consisting of rich purple bands alternating with yellowish white, are very beautiful. The mineral is difficult to work because brittle. Fluorite is also used to obtain hydrofluoric acid for etching. To etch glass, a picture, or whatever design it is desired to etch, is traced in the thin coating of wax with which the glass is first covered; a very small quantity of the liquid hydrofluoric acid is then washed over it; on removing the wax, in a few minutes, the picture is found to be engraved on the glass. The same process is used for etching seals, and any siliceous stone will be attacked with equal facility. This application of fluor spar depends upon the strong affinity between fluorine and silicon. Fluor

spar is also used as a flux to aid in reducing copper and other ores, and hence the name *fluor*.

Chlorocalcite (*Hydrophilite*). Calcium chloride. Vesuvius, Peru.

Gypsum.—Hydrous Calcium Sulphate.

Monoclinic; $I \wedge I = 143° 42'$; $2\dot{\imath} \wedge 2\dot{\imath} = 111° 42'$. Fig. 2, a common twin (or *arrow-head*) crystal. Cleavage parallel to broad face in Fig. 1, very easy, affording thin pearly flexible laminæ; in a cross direction, imperfect. Also in laminated masses; fibrous, with a satin lustre; in stellated or radiating forms consisting of narrow laminæ; also granular and compact.

1.

2.

When crystallized usually transparent or nearly so; the massive, translucent to opaque. Lustre pearly. Color white, gray, yellow, reddish, brownish, and even black. H. = 1·5–2, or so soft as to be scratched by the finger-nail. G. = 2·33. The plates bend in one direction and are brittle in another.

Composition. $CaO,S + 2\,aq$ (or $CaO + SO_3 + 2\,aq$) = Sulphur trioxide 46·5, lime 32·6, water 20·9 = 100. B.B. becomes instantly white and opaque and exfoliates; then fuses to a globule, having an alkaline reaction. In a closed tube much water is given off. Dissolves quietly in hydrochloric acid, and the solution gives a heavy precipitate with barium chloride.

The principal varieties are as follows:

Selenite: in transparent plates or crystal. Named from *selene*, the Greek for *moon*, alluding to the pearl-white appearance.

Radiated and *Plumose gypsum:* radiated in structure.

Fibrous gypsum, *Satin spar:* white and delicately fibrous.

Snowy gypsum and *Alabaster:* include the white or light-colored compact gypsum having a very fine grain.

Diff. Foliated gypsum resembles some varieties of heulandite, stilbite, talc, and mica; and the fibrous looks like fibrous carbonate of lime, asbestus and some of the fibrous zeolites; but gypsum in all its varieties is readily distinguished by its softness; its becoming B.B. opaque white through loss of water without fusion; by not effervescing or gelatinizing with acids. Moreover, on adding a little

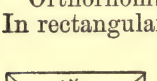
water to the powder obtained by heating, the water is taken up and the whole becomes solid.

Obs. Gypsum forms extensive beds in certain limestones and clay beds, and also occurs in volcanic regions. Selenite and snowy gypsum occurs in limestone near Lockport, at Camillus, Manlius, and Troy, N. Y.; in Davidson Co., Tenn.; crystals (Fig. 1), at Poland and Canfield, Ohio; groups of crystals at St. Mary's in Maryland; in Mammoth Cave, Ky., alabaster, in imitation of flowers, leaves, shrubbery, and vines. Alabaster is obtained at Castelino in Italy, 35 miles from Leghorn. Massive gypsum is abundant in N. York, from Syracuse to the western extremity of Genesee County; in New Brunswick, especially at Hillsboro', where part is excellent alabaster; in Hants, Colchester, and other districts, Nova Scotia; in Ohio, Michigan, Illinois, Virginia, Tennessee, Kansas, Arkansas, Texas, Iowa; and in connection with the Triassic beds of the Rocky Mountain region, abundant in Nevada, California, Colorado, Montana, Dakota, N. Mexico, Arizona. Abundant also in Europe.

Gypsum, when calcined and reduced to powder, is *plaster of paris*, and is used for taking casts, making models, and for giving a *hard finish* to walls. *Alabaster* is cut into vases and various ornaments, statues, etc. It owes its beauty for this purpose to its snowy whiteness, translucency, and fine texture. Moreover, owing to its softness, it can be cut or carved with common cutting instruments. Ground gypsum is used for improving soils.

Anhydrite.—Anhydrous Calcium Sulphate.

Orthorhombic; $I \wedge I = 100° 30'$; $1\breve{\imath} \wedge 1\breve{\imath} = 85°$ and $95°$. In rectangular and rhombic prisms; cleaves easily in three directions, into square blocks. Also fibrous and lamellar, often contorted; coarse and fine granular, and compact.



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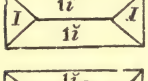

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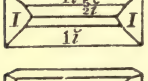


3.

Color white, or tinged with gray, red, or blue. Lustre more or less pearly. Transparent to subtranslucent. H. = 3–3·5. G. = 2·95–2·97.

Composition. CaO_4S (or $CaO + SO_3$) = Sulphur trioxide 58·8, lime 41·2 = 100. It is an *anhydrous* calcium sulphate. B.B. and with acids, its reactions are like those of gypsum, except that in the closed tube it gives no water.

A scaly massive variety containing a little silica has been named *Vulpinite;* contorted concretionary kinds are sometimes called *Tripestone.* Anhydrite is called by miners *hard-plaster,* because harder than gypsum.

Diff. Its square forms of crystallization and its breaking or cleaving into square blocks are good distinguishing characters; it looks as if the crystallization were cubic; but there is some difference in the ease of cleavage in the three directions.

Obs. Fine blue with gypsum and calc spar in black limestone at Lockport, N. Y.; near Windsor, N. Scotia; at Hillsboro', N. Brunswick. Foreign localities are at the salt-mines of Bex in Switzerland, Hall in the Tyrol, Ischl in Upper Austria, Wieliczka in Poland, and elsewhere.

The vulpinite variety is sometimes cut and polished for ornamental purposes.

Ettringite. Hydrous calcium-aluminium sulphate; in minute hexagonal crystals. District of Laach, in limestone.

Ulexite.—Boronatrocalcite. Calcium-sodium Borate.

In interwoven fibres, or capillary crystals, making small rounded masses. H. = 1. G. = 1·65. Lustre silky. Color white to gray. Tasteless.

Composition. Hydrous calcium-sodium borate. B.B. fuses very easily; wet with sulphuric acid and heated B.B. the flame is momentarily deep green.

Obs. From the dry plains of Iquique, and in Tarapaca, between Peru and Chili; Windsor, Brookville, and Newport, N. Scotia; Columbus Marsh and Thiel Salt Marsh, Nev., alternating with layers of salt.

Valuable as a source of borax. *Franklandite* is similar; from Peru.

Bechilite. A hydrous calcium borate. Occurs as an incrustation at the Tuscan lagoons, Italy. A "hydrous borate of lime" reported by Hayes from Iquique, Peru, has been called *Hayesine;* but its composition has been questioned, it being referred to Ulexite.

Priceite. A hydrous calcium borate; white, chalky; G. = 2·262; formula deduced $Ca_3O_{15}B_4 + 6$ aq (or $3CaO + 4BO_3 + 6$ aq). Forms a compact layer and large masses, 5 m. N. of Chetko, in Curry Co., Oregon. *Cryptomorphite* may be the same as priceite; and if so has priority in name. Windsor, N. Scotia.

Pandermite. Like priceite; H. = 3; G. = 2·48; formula deduced $Ca_2O_{11}B_3 + 3$ aq. In gray gypsum. Panderma, Black Sea.

Colemanite. Like pandermite in formula except 5 aq for 3 aq.

monoclinic; in fine glassy crystals, white to colorless, and massive; H. = 4. G. = 2·43. San Bernardino Co. and Death Valley in Inyo Co., Cal.

Hydroboracite. A hydrous calcium-magnesium borate, resembling gypsum in aspect.

Howlite. A hydrous calcium borate containing silica; Windsor, Nova Scotia; called also *Silicoborocalcite.*

Scheelite.—Calcium Tungstate.

Tetragonal. Also massive. Lustre vitreous, inclining to adamantine. Color white, pale yellowish, brownish, greenish, reddish. Transparent-translucent. H. = 4·5–5. G. = 5·9–6·1.

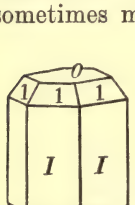
Composition. CaO_4W (or $CaO + WO_3$). B.B. fuses with much difficulty to a transparent glass. *Cuproscheelite* has part of the calcium replaced by copper.

Diff. Unlike calcite, and other minerals like it, in its high specific gravity, and non-effervescence with acids.

Obs. From Monroe, Ct.; Flowe Mine, N. C.; with gold, at Warren Mine, Idaho, and Golden Queen Mine, in Colorado; in Mammoth Mining Dist., Nev.; Seattle, Washington T.; Caldbeck Fell, England; in Bohemia; Hartz; Saxony; Hungary; Sweden; Vosges; Adelong, N. S. W.

Apatite.—Calcium Phosphate.

Hexagonal. Usually in hexagonal prisms; $O \wedge 1 = 139° 42'$. Cleavage imperfect. Occasionally massive; sometimes mammillary with a compact fibrous structure.



Color usually greenish, often yellowish green, bluish green, and grayish green; sometimes yellow, blue, reddish, brownish, colorless. Lustre vitreous to subresinous. Transparent to opaque. H. = 5. G. = 3·18–3·25. Brittle.

Composition. $Ca_3O_8P_2 + \frac{1}{3}Ca(Cl_2, F_2)$ (or $3CaO + P_2O_5 + \frac{1}{3}Ca(Cl_2, F_2)$ = if without fluorine, Phosphorus pentoxide 40·92, lime 53·80, chlorine 6·82 = 100. When chlorine is present in place of fluorine it is called *chlor-apatite*, and when the reverse, *fluor-apatite.* B.B. infusible except on the edges. Dissolves slowly in nitric acid without effervescence. Some varieties phosphoresce when heated, and some become electric by friction. Its constituents are contained in the bones

and ligaments of animals, and the mineral has probably been derived in many cases from animal remains.*

Massive apatite is often called *Phosphorite;* the pale yellowish-green crystals, *Asparagus stone. Osteolite* is a white earthy apatite. *Eupyrchroite* is a fibrous mammillary variety from Crown Point, Essex Co., N. Y.

Fossil excrements, called *coprolites,* occur in stratified rocks, and the material sometimes constitutes extensive beds; it is chiefly calcium phosphate. *Guano* is of this origin, and consists of calcium phosphate along with more or less of hydrous phosphates and some impurities.

Diff. Distinguished from beryl by its inferior hardness, it being easily scratched with a knife; from calcite by no effervescence with acids; from pyromorphite by its difficult fusibility, and giving B.B. no metallic reaction.

Obs. Apatite occurs in gneiss, mica schist, hornblende schist, granular limestone. In microscopic crystals it is sparingly present in almost all crystalline rocks, the igneous as well as metamorphic. The best crystals in the United States occur in granular limestone.

Large deposits occur in veins in the Archæan of Canada, especially the Ottawa region, which contain also much calcite and pyroxene, hornblende, phlogopite mica, and often zircon, titanite, scapolite, and other minerals. Some of the crystals of apatite in the veins are one to two feet in diameter, and weigh hundreds of pounds. The veins are extensively worked, producing 20,000 to 25,000 tons a year.

Other localities are Edenville and Amity, Orange Co., N. Y.; Westmoreland, N. H., in a vein of feldspar and quartz; Blue Hill Bay, Auburn, Me.; Bolton, Chesterfield, Chester, Mass.; beautiful blue at Dixon's quarry, Wilmington, Del.

Named from the Greek *apatao,* to deceive, in allusion to the mistake of early mineralogists respecting the nature of some of its varieties.

When abundant, used, like guano, as a fertilizer, on account of its phosphoric acid. To make it capable of being taken up by plants it is treated first with a small portion of sulphuric acid, which renders the phosphoric acid soluble.

* Bones contain 25 per cent. of calcium phosphate, with some fluoride of calcium, 3 to 12 per cent. of calcium carbonate, some magnesium phosphate and sodium chloride, besides 33 per cent. of animal matter.

When guano has been accumulated by birds, or other animals, over coral rock, a calcium carbonate, (as on some coral islands,) the waters in filtrating through it have often carried down the soluble phosphoric acid or phosphates into the underlying beds, turning them into calcium phosphate.

Spodiosite is probably an apatite pseudomorph.

Herderite. Calcium-beryllium fluo-phosphate; orthorhombic; yellowish, greenish white. Ehrenfriedersdorf, Saxony; Stoneham, Me.

Brushite and *Metabrushite.* Hydrous calcium phosphates. Found in guano. *Monetite* and *monite* are other guano substances.

Pyrophosphorite. A white, earthy phosphate; analysis gave it the composition of a pyrophosphate. A guano deposit in the W. Indies.

Pharmacolite. A hydrous calcium arsenate.

Haidingerite. Another hydrous calcium arsenate.

Berzeliite. Calcium-magnesium arsenate; isometric; yellow; G. = 4–4·1. *Caryinite* is related in composition but is not isometric. Both from Longban, Sweden.

Nitrocalcite. Hydrous calcium nitrate. From caverns.

Pyrochlore. A calcium-cerium niobate; in small brown and brownish yellow isometric octahedrons; G. = 4·3–4·5. Norway; Miask, Siberia.

Microlite. In isometric octahedrons, like pyrochlore; color brown; G. = 5·5–6, in composition a calcium tantalate. Chesterfield, Mass., Branchville, Ct.; Amelia Co., Va., Utö, Sweden. The crystals first found were small, whence the name; but some Virginia crystals weigh four pounds.

Disanalyte. A columbate and titanate of calcium, cerium, and iron; in cubes. The Kaiserstuhl, in granular limestone.

Romeite. Calcium antimonate; tetragonal; yellow.

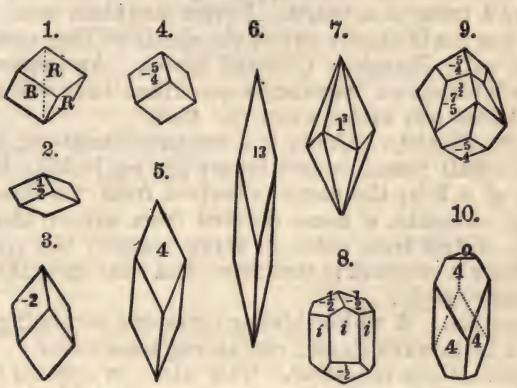
Atopite Another calcium antimonate in isometric crystals. Sweden. *Schneebergite* is another.

Calcite.—Calc Spar. Calcium Carbonate.

Rhombohedral; $R \wedge R$ (Fig. 1) = 105° 5′. Cleavage easy, parallel with R. Often fibrous; lustre silky; sometimes lamellar; often coarse or fine granular, and compact.

Color; when transparent, colorless, topaz-yellow, and rarely rose or violet; other crystalline varieties, white, gray, reddish, yellowish, rarely deep red, often mottled; when massive uncrystalline, of various dull shades, chalk-white, grayish white, gray, ochre-yellow, red, brown, and black. Lustre vitreous; of the finely fibrous, silky; of the uncrystalline, dull, often earthy. H. = 3. G. of pure crystals 2·715; 2·5–2·8.

Composition. CaO_2C (or $CaO + CO_2$) = Carbon dioxide 44, lime 56 = 100. Sometimes impure from mixture with other substances. B.B. infusible; colors the flame reddish; gives up its carbon dioxide, and becomes caustic, and alkaline in reaction; and by this process, carried on in lime-



kilns, limestone is burnt to *quicklime.* Effervesces in dilute cold hydrochloric acid. Many varieties phosphoresce when heated.

The following are the principal varieties:

Iceland spar. Transparent crystalline calcite; formerly brought in large crystals from Iceland.

Dog-tooth spar. Has the form in Fig. 7.

Satin spar. Finely fibrous, with a satin lustre. Usually in veins.

Limestone. A general name for massive calcite as well as for massive dolomite.

Granular limestone. Lustre glistening, owing to its consisting of crystalline grains; the grains show the cleavages of crystals of calcite. Hence called *crystalline* limestone. The better kinds, valuable in the arts, are called *marble;* the coarser of them, *architectural* marble; the finer white, *statuary* marble; colored kinds, as well as white, when polished, ornamental marbles. The best marble is as white and fine-grained as loaf-sugar, which it much resembles. Often impure with pyrite, mica, tremolite, and other minerals.

Compact limestone. Dull in lustre unless polished, and

not distinctly granular in texture. Colors sometimes arranged in blotches or veins. The kinds that are handsome when polished and fit for ornamental purposes are included among marbles.

Chalk. White and earthy; without lustre; so soft as to leave a trace on a board. Forms mountain beds. Most chalk was made chiefly out of the shells of Rhizopods.

Hydraulic limestone (*Cement stone*). An impure limestone affording, on burning, a quicklime that will make a cement that sets under water (p. 459).

Oölite, Pisolite. Oölite is a compact limestone, consisting of small round concretionary grains, looking like the spawn of a fish; the name is derived from the Greek *oön*, an egg. Pisolite, a name derived from *pisum*, the Latin for *pea*, differs from oölite in being coarser; the spherules often have a concentric structure, and thus show their concretionary origin.

Argentine. A white shining limestone consisting of laminæ a little waving, and containing some silica.

Fontainebleau limestone. This name is applied to crystals of the form shown in figure 3, containing a large proportion of sand, and occurring in groups. They were formerly obtained at Fontainebleau, France, but the locality is exhausted.

Rock milk. White and earthy like chalk, but still softer, and very fragile. Deposited from waters containing lime in solution. *Rock meal* is a powdery variety.

Calcareous tufa. Formed by deposition from waters like rock milk, but more cellular or porous and not so soft.

Stalactite, Stalagmite. The name stalactite is explained on page 60. The deposits of the same origin that cover the floors of caverns are called stalagmite. They generally consist of differently colored layers, and appear banded or striped when broken. The so-called "Gibraltar rock" is stalagmite from a cavern in the rock of Gibraltar.

Thinolite. Calcite pseudomorphs, of prismatic and pyramidal forms, abundant in thick deposits in the basins of old lakes over the Great Basin west and southwest of the Great Salt Lake.

Travertine. Deposits from calcareous waters forming thick beds, as in the Gardiner River region of the Yellowstone Park, Tivoli (Tibur of the Romans) near Rome, where it was early called Tiburtine, and in many other regions.

Stinkstone, Anthraconite. Gives out a fetid odor when struck; caused by certain bituminous materials present in the rock.

Diff. Distinguished by being scratched easily with a knife; its strong effervescence in dilute acid; its complete infusibility. Less hard than aragonite, unlike it also in having a very distinct cleavage.

Obs. Calcite occurs in fine crystals at Rossie, N. Y., one crystal from there, now in the Peabody Museum at New Haven, weighing 165 pounds; in geodes of "dog-tooth spar" in limestone at Lockport, along with gypsum and pearl spar; at Leyden and Lowville, N. Y; at Bergen Hill, N. J., in beautiful wine-yellow crystals in amygdaloidal cavities; at the Lake Superior copper-mines; and elsewhere. *Argentine* occurs near Williamsburg and Southampton, Mass. *Rock milk* covers the sides of a cave at Watertown, N. Y., and is now forming. *Stalactites* of great beauty occur in Luray, Weir's, and other caves in Virginia and in the Western States. *Chalk* occurs in England and Europe; also in Western Kansas. Granular limestones are common in the Eastern and Atlantic States, and compact limestones in the Middle and Western States, and some beds of the former afford excellent marble for building and some of good quality for statuary.

In the state of *quicklime,* it is mixed with water and sand to make "mortar;" a calcium hydrate results which becomes slowly carbonated through carbonic acid in the atmosphere. See further the chapter on Rocks.

Aragonite.

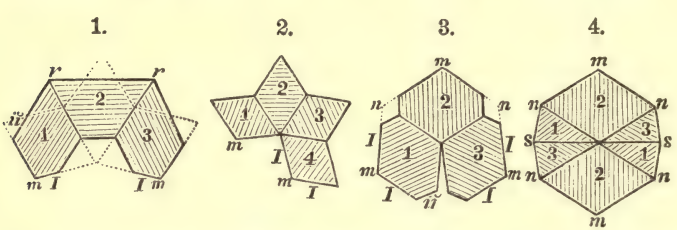
Orthorhombic; $I \wedge I = 116° 10'$. In rhombic prisms; usually in compound crystals having the form of a hexagonal prism, with uneven or striated sides; or in stellated forms consisting of two or three flat crystals crossing one another. Transverse sections of some of the compound crystals are shown in Figs. 1 to 4. Cleavage parallel to I, not very distinct. Also in globular and coralloidal shapes; also in fibrous seams in rocks.

Color white, or with light tinges of gray, yellow, green, and violet. Lustre vitreous. Transparent to translucent. H. = 3·5–4. G. = 2·93–2·936.

Composition. Same as for calcite; and B.B. with acids the same, except that it falls to powder readily when heated.

Diff. Distinguished from calcite by the absence of the cleavage of the latter, as well as the crystalline form; also by its higher specific gravity.

Obs. Aragonite occurs mostly in gypsum beds and in connection with iron ores; also in basalt and other rocks.



The coralloidal forms are found in iron ore beds, and are called *Flos ferri, flowers of iron.* They look like a loosely intertwined or tangled white cord.

The *flos-ferri* variety occurs at Lockport with gypsum; at Edenville, at the Parish ore bed in Rossie, N. Y., and in Chester Co., Pa. Aragon in Spain affords six-sided prisms, associated with gypsum; hence the name of the species. Also at Bilin, in Bohemia; Tarnowitz, in Silesia; and other places.

Dolomite.—Calcium-Magnesium Carbonate. Magnesian Limestone.

Rhombohedral; $R \wedge R = 106° 15'$. Cleavage perfect parallel to R. Faces of rhombohedrons sometimes curved, as in the annexed figure. Often granular and massive, constituting extensive beds.

Color white, or tinged with yellow, red, green, brown, and sometimes black. Lustre vitreous or pearly. Nearly transparent to translucent. Brittle. H. = 3·5–4. G. = 2·8–2·9.

Composition. $\frac{1}{2}Ca\frac{1}{2}MgO_3C$ (or $(\frac{1}{2}Ca\frac{1}{2}Mg)O + CO_2$) = Calcium carbonate 54·35, magnesium carbonate 45·65 = 100. Some iron or manganese is often present, replacing part of the magnesium or calcium. Iron-bearing varieties become brown on exposure, and the manganese-bearing, black, yielding as the ultimate result generally limonite, and oxide of manganese.

The principal varieties of this species are as follows:

Dolomite. White, crystalline granular, often not distinguishable in external characters from granular limestone.

Pearl spar. In pearly rhombohedrons with curved faces.

Rhomb spar, Brown spar. In rhombohedrons, which become brown on exposure, owing to their containing 1 to 10 per cent. of oxide of iron or manganese.

A cobaltiferous variety has a red tint. A white compact siliceous variety has been called *Gurhofite.* Some hydraulic limestones are dolomite.

Diff. Distinctive characters nearly the same as for calcite. It is harder than that species, and differs in the angles of its crystals, and effervesces in acids very feebly, unless heated; but chemical analysis is often required to distinguish them.

Obs. Common as marble in western New England and southeastern New York, and constitutes much of that used for building; and the uncrystalline constitutes many of the limestones of New York and the States farther west and south. Crystallized specimens have been obtained at the Quarantine, Richmond Co., N. Y.; large at Brewster, N. Y., and Alexander Co., N. C.; rhomb spar occurs in talc, at Smithfield, R. I.; Marlboro', Vt.; Middlefield, Mass.; pearl spar in crystals of the above form at Lockport, Niagara Falls, Rochester, Glen's Falls; gurhofite on Hustis's farm, Phillipstown, N. Y.

Dolomite was named in honor of the geologist and traveller Dolomieu.

Burns to quicklime like calcite. The white massive variety is used extensively as marble. The magnesian lime has been supposed to injure soils; but this is believed not to be the case if it is air-slaked before being used. It is employed in England in the manufacture of Epsom salts or magnesium sulphate.

Ankerite. Resembles brown spar, and, like that, becomes brown on exposure. $R \wedge R = 106° 12'$. A calcium-magnesium-iron-manganese carbonate. The Styrian iron ore beds of Saltzburg are some of its foreign localities. Occurs in Nova Scotia; in quartz veins in western New Hampshire; Quebec, Canada, etc. *Parankerite* is a variety of it.

Hydrodolomite. A calcium-magnesium carbonate containing water. *Pennite* from Texas, Pa., is similar.

Whewellite. Calcium oxalate. In monoclinic crystals, England; coal-bed near Dresden.

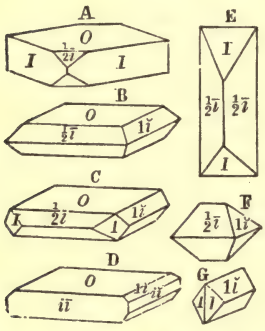
Thaumasite. Mixture of carbonate and sulphate. Sweden.

BARIUM AND STRONTIUM.

Barium and strontium occur in nature only in anhydrous ternary compounds of the following kinds: sulphate, carbonate, silicate; and in silicates only in combination with other basic elements. The species are characterized by high specific gravity, ranging from 3·5 to 4·8. Strontium gives a red color to the blowpipe flame; and barium, if strontium and other basic elements are absent, a characteristic green color.

Barite.—Heavy Spar. Barytes. Barium Sulphate.

Orthorhombic; $I \wedge I = 101° 40'$; $O \wedge \frac{1}{2}\breve{i} = 141° 08'$; $O \wedge 1\breve{i} = 127° 18'$. Forms as in figures. Cleavage I, O, perfect. Massive varieties often coarse lamellar; also columnar, fibrous, granular, and compact. Color white, sometimes tinged yellow, red, brown, blue, or dark brown. Lustre vitreous; sometimes pearly. Transparent or translucent. H. = 2·5–3·5. G. = 4·3–4·7; 4·48 of pure crystals.



Composition. BaO_4S (or $BaO + SO_3$) = Sulphur trioxide 34·3, baryta 65·7 = 100. Strontium and calcite are sometimes present replacing a little barium. B.B. fuses to a bead which reacts alkaline; imparts a green color to the flame. After fusion with soda in the reducing flame on coal, if placed on a silver coin and moistened, it produces a black stain, due to sulphur.

Diff. Distinguished by its specific gravity, the inaction of acids, and its hardness.

Often present in mineral veins as the gangue of the ore. Occurs in this way, and also by itself, at Cheshire, Ct.; Hatfield, Mass.; Rossie and Hammond, N. Y.; Perkiomen, Pa., and the lead-mines of the Mississippi Valley. Scoharie, and Pillar Point near Sackett's Harbor, are other localities; also near Fredericksburg, Marion, and Irvington, Va.; N. Scotia, etc.

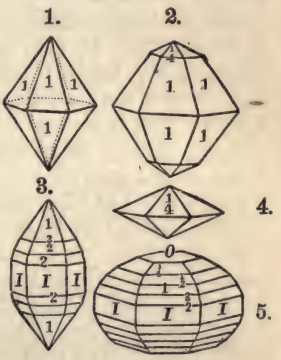
"Barytes," or barite, is ground up and used to adulterate

white lead. When white lead is mixed in equal parts with it, it is sometimes called *Venice white*, and another quality with twice its weight of barite is called *Hamburg white*, and another, one-fourth white lead, is called *Dutch white*. When the material is very white, a proportion of it gives greater opacity to the color, and protects the lead from being speedily blackened by sulphurous vapors; and these mixtures are therefore preferred for certain kinds of painting. 20,000 tons are ground up annually in the U. States.

Dreelite. A barium-calcium sulphate. Beaujeu, France.

Witherite.—Barium Carbonate.

Orthorhombic; $I \wedge I = 118° 30'$. Cleavage imperfect. Also in globular or botryoidal forms; often massive, and either fibrous or granular. Color yellowish or grayish white to white when in crystals. Translucent to transparent. Lustre a little resinous when massive. H. = 3–4. G. = 4·29–4·35. Brittle.



Composition. BaO_2C (or $BaO + CO_2$) = Carbon dioxide 22·3, baryta 77·7 = 100. B.B. decrepitates; fuses easily, tinging the flame green, to a translucent globule, which becomes opaque on cooling, and colors moistened turmeric paper red. Effervesces in hydrochloric acid.

Diff. Distinguished, by its specific gravity and fusibility, from calcite and aragonite; by its action with acids, from allied minerals that are not carbonates; by yielding no metal, from cerussite, and by tingeing the flame green, from strontianite.

Obs. Important foreign localities are Fallowfield in Northumberland (where it is mined), Alstonmoor in Cumberland, Anglezark in Lancashire; Silesia; Styria; Sicily. In the U. States, Lexington, Ky.

Witherite, from Fallowfield, is used in chemical works, in the manufacture of plate-glass, and in France in the manufacture of beet sugar.

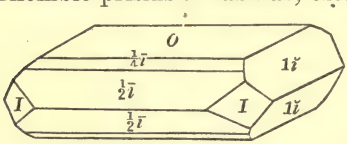
Barytocalcite. Barium-calcium carbonate; in monoclinic crystals; white; H. = 4; G. = 3·6-3·7. Alston-Moor, England.

Bromlite. Of same composition, but orthorhombic. Bromley Hill, and Northumberland, England.

Nitrobarite. Barium nitrate; soluble. Chili.

Celestite.—Strontium Sulphate.

Orthorhombic; $I \wedge I = 103° 30'$ to $104° 30'$. Crystals rhombic prisms or tabular; often long and slender. Cleavage distinct parallel with *I*. Also columnar or fibrous; rarely granular. Color white; slightly bluish; sometimes clear white or reddish. Lustre vitreous or a little pearly. Transparent to translucent. H. = 3–3·5. G. = 3·9–4. Brittle.



Composition. SrO_4S (or $SrO + SO_4$) = Sulphur trioxide 43·6, strontia 56·4 = 100. B.B. decrepitates and fuses, tingeing the flame bright red, to a milk-white globule, giving an alkaline reaction. With soda on coal fuses to a mass which when moistened blackens silver.

Diff. Differs from barite, by the bright red color of the flame B.B., and its less specific gravity; and from the carbonates, by not effervescing with acids.

Obs. Found in beds of sandstone or limestone, and also with gypsum, rock salt, and clay. Bluish tabular and prismatic crystals, at Strontian Island, Lake Erie; Schoharie, Lockport, and Rossie, N. Y.; handsome fibrous at Franktown, Huntingdon County, and Bell's Mills, Blair Co., Pa. Sicily affords fine crystallizations associated with sulphur.

The pale *sky-blue* tint, so common with the mineral, gave origin to the name *celestite.*

Used in the arts for making nitrate of strontia, which is employed for producing a red color in fireworks.

Strontianite.—Strontium Carbonate.

Orthorhombic; $I \wedge I = 117° 19'$. Cleavage parallel to *I*, nearly perfect. Also fibrous and granular; sometimes in globular shapes, radiated within.

Color pale greenish white; also white, gray, and yellowish brown. Lustre vitreous, or somewhat resinous. Trans-

parent to translucent. H. = 3·5–4. G. = 3·6–3·72. Brittle.

Composition. SrO_3C (or $SrO + CO_2$) = Carbon dioxide 29·7, strontia 70·3 = 100. Some strontium often replaced by calcium. B.B. swells, throws out little sprouts, but does not fuse. Colors the flame bright red; after heating, possesses an alkaline reaction. Effervesces in cold dilute acid; sulphuric acid gives a precipitate of strontium sulphate.

Diff. Its effervescence with acids distinguishes it from minerals that are not carbonates; the color of the flame B.B., from witherite and other carbonates; calcium salts also give a red color to the flame, but the shade is yellowish and less brilliant.

Obs. In limestone at Schoharie, N. Y., both in crystals, fibrous, and massive; in Jefferson Co., N. Y.; Mifflin Co., Pa. Strontian in Argyleshire, England, was the first locality known, and gave the name to the mineral, whence the metal strontium; occurs there, with galenite, in stellated and fibrous groups, and in crystals.

Used for preparing the strontium nitrate.

POTASSIUM AND SODIUM.

Potassium and sodium occur in nature in the state of chloride, sulphate, nitrate, and carbonate, and are constituents in many silicates.

Sylvite.—Potassium Chloride.

Isometric; crystals often cubes with octahedral planes (Fig. 8, p. 19). White or colorless. Lustre vitreous. Taste nearly that of common salt. H. = 2. G. = 1·9–2.

Composition. KCl = Chlorine 47·5, potassium 52·5 = 100. From Vesuvius and Stassfurt.

Other potassium chlorides containing iron, p. 200.

Halite.—Common Salt. Sodium Chloride.

Isometric. In cubes, and related forms. Sometimes in shallow concave hopper-shaped crystals formed by the enlargement at the margin of a floating crystal. Cleavage cubic, perfect.

Color white or grayish, sometimes rose-red, yellow, and of amethystine tints. Taste saline. H. = 2. G. = 2·257.

Composition. NaCl = Chlorine 60·7, sodium 39·3 = 100. Crackles or decrepitates when heated; fuses easily, coloring the flame deep yellow. A variety from Chili (*Huantajayite*) contains 11 p. c. of silver chloride.

Diff. Distinguished by its solubility and taste.

Obs. Occurs in extensive but irregular beds, usually associated with gypsum, anhydrite, and clays or sandstone. Exists in formations of all ages, from the Silurian to the present time. Found in the Pyrenees, in the valley of Cardona, and elsewhere, forming hills 300 to 400 feet high; in Poland and Wieliczka; at Hall in the Tyrol, and along a range through Reichenthal in Bavaria, Hallein in Salzburg, Hallstadt, Ischl and Ebensee in Upper Austria, and Aussee in Styria; in Hungary at Marmoros and elsewhere; in Transylvania, Wallachia, Galicia, and Upper Silesia; at Vic and Dieuze in France; at Bex in Switzerland; in Cheshire, England; in Northern Africa in vast quantities, forming hills and extended plains; in Northern Persia at Tiflis; in India in the province of Lahore and in the valley of Cashmere; in China and Asiatic Russia; in South America, in Peru and the Cordilleras of New Granada.

Among the most remarkable deposits are those of Poland and Hungary. The former, near Cracow, have been worked since the year 1251, and it is calculated that there is still enough salt remaining to supply the whole world for many centuries. Its deep subterranean regions are excavated into houses, chapels and other ornamental forms, the roof being supported by pillars of salt; and when illuminated by lamps and torches they are objects of great splendor.

The salt is often impure with clay, and is purified by dissolving it in large chambers, drawing it off after it has settled, and evaporating it again. The salt of Norwich (in Cheshire) is in masses 5 to 8 feet in diameter, which are nearly pure, and it is prepared for use by crushing it between rollers.

In North America, beds of rock salt exist at Goderich in Canada; at Wyoming and other places in western New York (reached by boring to a depth of 1000 feet or more); in West Virginia on the Great Kanawha, etc.; extensively at Petite Anse, La., where it underlies 144 acres; in Nevada, Montana, Utah, Wyoming, Idaho, Dakota, New Mexico, California; in the Salmon River Mts., Oregon.

Brine springs also proceed from rocks of various ages;

and often they are indications of deep-seated beds of rock salt.

The salt of western New York, and Goderich, Canada, is of the Salina period of the Upper Silurian; the brine springs of Michigan, Ohio, and Kanawha, from shales and marlytes of the Carboniferous age; those of the salt beds of Norwich, England, in magnesian limestone of the Permian; those of the Vosges and of Salzburg, Ischl, and the neighboring regions, in marly sandstone of the Triassic; those of Bex, in Switzerland, in the Lias formation; that of Wieliczka, Poland, and the Pyrenees, in the Cretaceous or Chalk formation; that of Catalonia, in the Tertiary; that of Louisiana, in the Quaternary, and large deposits are still more recent; and, besides, there are lakes that are now evaporating and producing salt depositions.

Vast lakes of salt water exist in many parts of the world. The Great Salt Lake of Utah has an area of 2000 square miles, and is remarkable for its extent, considering that it is situated at an elevation of 4200 feet above the sea. The dry regions of the Great Basin and of Southeastern California are noted for salt licks and lakes. In Northern Africa large lakes as well as hills of salt abound, and the deserts of this region and Arabia abound in saline efflorescences. The Dead and Caspian seas, and the lakes of Khoordistan, are salt. From 20–26 parts in a hundred of the weight of the water from the Dead Sea are solid salts, of which 10 parts are common salt. Over the pampas of La Plata and Patagonia there are many ponds and lakes of salt water.

The greater part of the salt made in Eastern North America is obtained by evaporation from salt springs, and Michigan and New York are the chief sources. At the best springs at Syracuse, N. Y., a bushel of salt is obtained from every 40 gallons. But the discovery of rock salt at Wyoming, and elsewhere west of Syracuse, may make the brines of New York of comparatively little value.

The process of evaporation under the heat of the sun is extensively employed in hot climates for making salt from sea water, which affords a bushel for every 300 or 350 gallons. For this purpose a number of large shallow basins are made adjoining the sea; they have a smooth bottom of clay, and all communicate with one another. The water is let in at high tide and then shut off for the evaporation to

go on. This is the simplest mode, and is used even in uncivilized countries, as among the Pacific Islands.

The salt product of the U. States in 1884 was about 32,575,000 bushels (or a fifth of this number of barrels); of which 15,810,000 was from Michigan, 8,940,000 from New York; 1,750,000 from Ohio, and 1,600,000 from W. Virginia. In 1885, it was 35,200,000 bushels.

Mirabilite.—Glauber Salt. Hydrous Sodium Sulphate.

Monoclinic. (Figure, p. 42.) In efflorescent crusts of a white or yellowish-white color; also in many mineral waters. Taste cool, then feebly saline and bitter.

Composition. $Na_2O_4S + 10$ aq (or $Na_2O + SO_3 + 10$ aq) = Sulphur trioxide 24·8, soda 19·3, water 55·9 = 100.

Diff. Distinguished from Epsom salt, for which it is sometimes mistaken, by its coarse crystals, and the yellow color it gives to the blowpipe flame.

Manufactured from common salt, its production being one stage in the manufacture of sodium carbonate.

Obs. From Aussee, Austria; Sicily; Tarapaca; etc.; on Hawaii, in a cave at Kailua, where it is now forming; in efflorescences on the limestone below Genesee Falls, near Rochester, N. Y.; Sweetwater Valley, Wyoming; Morrison, Cal.; New Mexico.

The artificial salt was first made by a German chemist by the name of Glauber.

Aphthitalite (*Arcanite*). Potassium sulphate, K_2O_4S = Sulphate trioxide 45·9, potash 54·1 = 100. Vesuvius.

Misenite. Hydrous potassium sulphate. A cavern near Misene.

Thenardite. Sodium sulphate, Na_2O_4S = Sulphur trioxide 43·7, soda 56·3 = 100. Spain; Bolivia; Tarapaca, in Peru; Slate Range, San Bernardino Co., Cal.; in Nevada; on the Rio Verde, Arizona.

Glauberite. Sodium-calcium sulphate; in monoclinic crystals. Villa Rubia, in New Castile; Aussee, Austria; and other salt beds.

Syngenite. Hydrous potassium-calcium sulphate. East Galicia.

Wattevillite. Hydrous sodium-potassium-calcium sulphate. Bavaria.

Tarapacaite. Potassium chromate; yellow. Tarapaca.

Borax.—Hydrous Sodium Biborate. Tinkal.

Monoclinic; $I \wedge I = 87°$. Cleavage parallel with i-i perfect. Crystals white or colorless; often transparent; lustre vitreous. H. = 2–2·5. G. = 1·716. Taste sweetish-alkaline.

Composition. $Na_2O_7B_4 + 10$ aq (or $Na_2O + 2B_2O_3 + 10$ aq) = Boron trioxide 36·6, soda 16·2, water 47·2 = 100. B.B. swells up to many times its bulk, becomes opaque white, and finally fuses to a glassy globule.

Obs. Originally brought from a salt lake in Thibet, where it is dug in masses from the edges and shallow parts of the lakes; deposition is now going on. Crude borax was formerly sent to Europe under the name of *tinkal*, and there purified for the arts. Also found in Asiatic Turkey, Peru, and Ceylon. Has been extensively made from the boracic acid of the Tuscan lagoons by the reaction of this acid on sodium carbonate. The borax of commerce is in part made from ulexite and lime-borate (p. 231).

Occurs under like circumstances in California and Nevada, or is manufactured from other borates in solution. Localities in California are Clear Lake and vicinity; near Walker's Pass, Sierra Nevada; at Mono and Owens Lakes, and at Death Valley, in Inyo Co., Cal., near the borders of Nevada; in the Slate Range Marsh, in San Bernardino Co., Cal.; in Churchill Co., Nev.; at Little Salt Lake, near Ragtown, on the Pacific Railroad, and in Esmeralda Co., at Columbus, Teel's and Rhodes' Marshes, and in Fish Lake Valley. The large deposits of "priceite" in Southern Oregon, and of ulexite (p. 231) in the "Cane Spring District," 20 miles west of San Bernardino, and at the Columbus Marsh, are other sources of borax. The amount of California and Nevada borax produced in 1876 was 5,180,910 lbs.; in 1880, 3,860,748 lbs.; in 1882, 4,236,291 lbs.; in 1884, 7,000,000 lbs.; in 1885, 8,000,000 lbs.

Tincalconite. Efflorescence on borax. California.

Nitre.—Potassium Nitrate.

Orthorhombic; $I \wedge I = 118° 50'$. In modified right rhombic prisms. Usually in thin, white crusts, and in acicular crystals. Taste saline and cooling. H. = 2. G. = 1·97.

Composition. KO_3N (or $K_2O + N_2O_5$) = Nitrogen pentoxide (N_2O_5) 53·4, potash 46·6. Burns vividly on a live coal.

Diff. Distinguished by the taste, and vivid action on a live coal; and from sodium nitrate, which it most resembles, by not becoming liquid on exposure to the air.

Obs. Occurs in many of the caverns of Kentucky and Indiana, etc., scattered through the earth that forms the floor of caves, and in many of the States and Territories of the far West. In procuring it, the earth is lixiviated, and the lye, when evaporated, yields the nitre.

India is its most abundant locality, where it is obtained largely for exportation. This salt forms on the ground in the hot weather succeeding copious rains, and appears in silky tufts or efflorescences; these are brushed up by a kind of broom, lixiviated, and after settling, evaporated and crystallized. In France, Germany, Sweden, Hungary, and other countries, there are artificial arrangements called *nitriaries* or nitre beds, from which nitre is obtained by the decomposition mostly of the nitrates of lime and magnesia which form in these beds. Refuse animal and vegetable matter putrefied in contact with calcareous soils produces nitrate of lime, which affords the nitre by reaction with carbonate of potash. Old plaster lixiviated affords about 5 per cent. This last method is much used in France. Nitrification takes place through the agency of a peculiar kind of microscopic plant, related to the bacteria.

Nitre, called also saltpetre, is employed in making gunpowder, forming 75 to 78 per cent. in shooting powder, and 62 in mining powder. The other materials are sulphur (10 per cent. for shooting powder to 20 for mining) and charcoal (12 to 14 for shooting powder and 18 for mining). It is also extensively used in the manufacture of nitric and sulphuric acids; also for pyrotechnic purposes, fulminating powders, and sparingly in medicine.

Nitratine.—Soda Nitre. Sodium Nitrate. Cubic Nitre.

Rhombohedral; $R : R = 106° 33'$. Also in crusts or efflorescences, of white, grayish, and brownish colors. Taste cooling. Soluble and very deliquescent.

Composition. NaO_3N (or $Na_2O + N_2O_5$) = Nitrogen pentoxide 63·5, soda 36·5 = 100. Burns vividly on coal, with a yellow light.

Diff. Resembles nitre (saltpetre), but deliquesces, and gives a deep yellow light when burning.

Obs. In the district of Tarapaca, Northern Chili, it covers the dry Pampa for an extent of forty leagues, mixed with gypsum, common salt, glauber salt, and remains of

recent shells; in Humboldt Co., Nev.; New Mexico; near Calico, Cal.

Used extensively in the manufacture of nitric acid; also in making nitre by replacing the sodium by potassium.

Natron.—Hydrous Sodium Carbonate. Carbonate of Soda.

Monoclinic. Generally in white efflorescent crusts, sometimes yellowish or grayish. Taste alkaline. Effloresces on exposure, the surface becoming white and pulverulent.

Composition. $Na_2O_3C + 10$ aq (or $Na_2O + CO_2 + 10$ aq) = Carbon dioxide 26·7, soda 18·8, water 54·5 = 100. Effervesces strongly with acids.

Diff. Distinguished from other soda salts by effervescing, and from trona, by efflorescing on exposure.

Obs. Found in solution in certain waters, from which it is crystallized in efflorescences by evaporation. Abundant in the soda lakes of Egypt; also in lakes at Debreczin, in Hungary; in the alkali flats of the Great Basin, abundant; in Carbon Co., Wyoming, where are over 100 soda lakes, 20 to 300 acres in area, and 15 to 45 feet deep.

This salt (but the artificially prepared) is extensively used in the manufacture of soap and glass, and for many other purposes.

Trona. Hydrous sodium sesquicarbonate. Occurs in the province of Suckenna, in Africa, between Tripoli and Fezzan, constituting a fibrous layer an inch thick beneath the soil; abundant at a lake in Maracaibo, 48 miles from Mendoza; an extensive bed in Churchill Co., Nev.

Thermonatrite. Hydrous sodium carbonate, $Na_2O_3C + aq$.

Gay-Lussite. White; brittle; monoclinic; composition $\frac{1}{2}Na_2CaO_3C + 2\frac{1}{2}$ aq. Lagunilla, in Maracaibo; Little Salt Lake, near Ragtown, Nev.

Hanksite. Sodium sulphato-carbonate in hexagonal crystals. California.

AMMONIUM.

The salts of ammonia are more or less soluble in water, and are entirely and easily volatilized before the blowpipe. When treated with caustic lime or potassa, ammonia is liberated, and is recognized by its odor and the reaction of the vapors on test papers.

Salmiak.—Sal Ammoniac, Ammonium Chloride.

In white crusts or efflorescences, often yellowish or gray.

Translucent—opaque. Taste saline and pungent. Soluble in three parts of water.

Composition. NH_4Cl = Chlorine 66·3, ammonium 33·7 = 100. Gives off the odor of *ammonia* when powdered and mixed with quicklime.

Obs. Occurs in many volcanic regions, as at Etna, Vesuvius, and the Sandwich Islands, where it is a product of volcanic action. Occasionally found about ignited coal seams.

Sal ammoniac is one of the products found in the soot and smoke of both wood and coal fires. The sal ammoniac of commerce was formerly manufactured from animal matter or coal soot. In Egypt, whence the greater part of this salt was obtained, the fires of the peasantry are made of the dung of camels; and the soot which contains a considerable portion of the ammoniacal salt is preserved and carried in bags to the works, where it is obtained by sublimation. But the ammoniacal liquor of the gas-works affords crude sulphate of ammonium, and from it, the sal ammoniac of commerce is now obtained by subliming a mixture of this sulphate with common salt (sodium chloride).

A valuable article in medicine. Employed by tinmen in soldering to prevent the oxidation of copper surfaces, and also in a variety of metallurgical operations.

Mascagnite. A hydrous ammonium sulphate; in mealy crusts, of a yellowish-gray or lemon-yellow color; translucent; taste pungent and bitter; *composition* $(NH_4)_2O_4S + H_2O$ = Sulphur trioxide 53·3, ammonia 22·8, water 23·9; easily soluble in water. Etna; Vesuvius; the Lipari Islands; the Guañape Isles, in guano. One of the products from the combustion of anthracite coal.

Lecontite. Hydrous ammonium-sodium sulphate. Near Comayagua, Central America.

Boussingaultite, hydrous ammonium-magnesium sulphate. Tuscany. *Hannayite* is another, in triclinic crystals, from guano in Victoria, with struvite.

Struvite. Hydrous ammonium-magnesium phosphate; in yellowish crystals, slightly soluble in water. Found on the site of an old church in Hamburg, where there had been quantities of cattle dung.

Tschermigite. An ammonia alum. Tschermig, Bohemia; Utah Co., Utah.

Larderellite. A white, tasteless, ammonium borate. Tuscan lagoons.

Hydrous ammonium phosphate and *Ammonium bicarbonate* (*Teschemacherite*) have been detected in guano; also, Hydrous sodium-ammonium phosphate, called *Stercorite.*

Cryptohalite. A probable ammonium fluosilicate. Vesuvius.

HYDROGEN.

Hydrogen is the basic constituent in hydrochloric acid, and in water.

Hydrochloric Acid.—Muriatic Acid, Hydrogen Chloride.

A gas, consisting of Chlorine 97·26, hydrogen 2·74 = 100 = HCl. It has a pungent odor, and is acrid to the skin. Rapidly dissolved by water. Passed into a solution of nitrate of silver, it produces a white precipitate (silver chloride) which soon blackens on exposure. Passes off whenever common salt is acted on by sulphuric acid; occasionally formed about volcanoes.

Hydrofluorite. Hydrofluoric acid or hydrogen fluoride. An emanation at some eruptions of Vesuvius, as observed by Scacchi.

WATER.

Water (hydrogen oxide) is the well-known liquid of streams and wells. The purest natural water is obtained by melting snow, or receiving rain in a clean glass vessel; but it is absolutely pure only when procured by distillation. It consists of hydrogen 1 part by weight, and oxygen 8 parts, or hydrogen 11·11, oxygen 88·89 = 100. It becomes solid at 32° Fahrenheit (or 0° Centigrade), and then crystallizes, and constitutes ice or snow. The crystals are of the hexagonal system. Flakes of snow consist of a congeries of minute crystals, and stars, like the figures on page 4, may often be detected with a glass. Various other allied forms are also assumed. The rays meet at an angle of 60°, and the branchlets pass off at the same angle with perfect regularity. The density of water is greatest at 39°·2 F.; below this it expands as it approaches 32°, and in the state of ice it is only 0·920. It boils at 212° F. A cubic inch of pure water at 62° F. and 30 inches of the barometer, weighs 252·458 grains, which equals 16.386 grams; and a cubic foot of water weighs 62·355 pounds avoirdupois. A pint, United States standard measure, holds just 7342 troy grains of water, which is little above a pound avoirdupois (7000 grains troy).

Water, as it occurs on the earth, contains some atmospheric air, without which the best would be unpalatable. This air, with some free oxygen also present, is necessary to the life of aquatic animals. In most spring water there is a minute proportion of salts of calcium (sulphate, chloride or carbonate), often with a trace of common salt, carbonate of magnesium, and some alumina, iron, silica, phosphoric acid, carbonic acid, and certain vegetable acids. These impurities constitute usually from $\frac{1}{10}$ to 10 parts in 10,000 parts by weight. The water of Long Pond, near Boston, contains about $\frac{1}{2}$ a part in 10,000; the Schuylkill of Philadelphia, about 1 part in 10,000; the Croton, used in New York City, 1 to $1\frac{1}{2}$ parts in 10,000. Nitric acid is usually found in rain-water combined with ammonia; river-waters are ordinarily the purest of natural waters, unless they have flowed through a densely populated region.

Sea-water contains from 32 to 37 parts of solid substances in solution in 1000 parts of water. The largest amount in the Atlantic, 36·6 parts, is found under the equator, away from the land or the vicinity of fresh-water streams; and the smallest in narrow straits, as Dover Straits, where there are only 32·5 parts. In the Baltic and Black Seas the proportion is only one third that in the open ocean. Of the whole, one half to two thirds is common salt (sodium chloride). The other ingredients are magnesium salts (chloride and sulphate), amounting to four fifths of the remainder, with sulphate and carbonate of calcium, and traces of bromides, iodides, phosphates, borates, and fluorides. The water of the British Channel affords water 964·7 parts in 1000, sodium chloride 27·1, potassium chloride 0·8, magnesium chloride 3·7, magnesium sulphate 2·30, calcium sulphate 1·4, calcium carbonate 0·03, with some magnesium bromide and probably traces of iodides, fluorides, phosphates and borates. The bitter taste of sea-water is owing to the salts of magnesium present.

The waters of the Dead Sea contain 200 to 260 parts of solid matter in 1000 parts (or 20 to 26 per cent.), including 7 to 10 per cent. of common salt, the same proportion of magnesian salts, principally the chloride, $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent. of calcium carbonate and sulphate, besides some bromides and alumina. The density of these waters is owing to this large proportion of saline ingredients.

Mineral waters vary much in constitution. They often

contain iron in the state of bicarbonate, like those of Saratoga and Ballstown, and are then called *chalybeate* waters, Hydrogen sulphide is often held in mineral waters and imparts to them its odor and taste; such are the so-called *sulphur springs*.

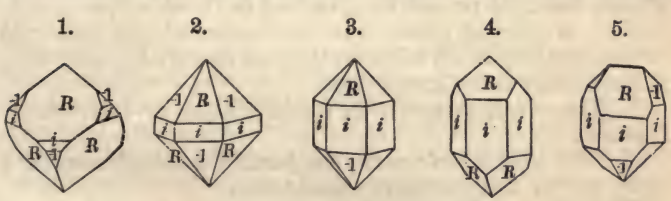
Minute traces of salts of zinc, arsenic, lead, copper, silver, antimony, and tin have been found in some waters. Whatever is soluble in a region through which waters flow will of course be taken up by them, and many ingredients are soluble in minute proportions which are usually described as insoluble.

III. SILICA AND SILICATES.

1. SILICA.

Quartz.

Rhombohedral; $R \wedge R = 94° 15'$. Usually in six-sided prisms, terminating in six-sided pyramids. No cleavage apparent, seldom even in traces; but sometimes obtained by heating and plunging the crystal into cold water.



Sometimes in coarse radiated forms; also coarse and fine granular (sandstone-like); also compact, crypto-crystalline (flint-like), either amorphous, or presenting stalactitic and mammillary shapes.

Often colorless; sometimes topaz-yellow, amethystine, rose, smoky, or other tints; also of various shades of yellow, red, green, blue, and brown colors to black; in some varieties the colors in bands, stripes, or clouds. Of all degrees of transparency to opaque. Lustre vitreous; of crystals splendent; of some massive forms, dull, often waxy. H. = 7. G. = 2·5–2·8; pure crystals 2·65.

Composition. SiO_2 = Oxygen 53·33, silicon 46·67 = 100. B.B. infusible; with soda, fuses with effervescence.

The common mineral impurities are chlorite, rutile, asbestus, actinolite, tourmaline, hematite, limonite. Hematite (red iron oxide) is the usual red coloring matter; limonite, mostly in the state of yellow ochre, the yellow and brownish yellow; chlorite and actinolite give a green color, and an oxide or silicate of nickel, an apple-green tint; manganese an amethystine; carbonaceous matters, such as color marsh waters, smoke-brown shades. Quartz crystals often contain liquids in cavities, either water, petroleum or naphtha-like material, or liquid carbon dioxide (p.). Chalcedony usually has more or less of disseminated opal; and clear quartz is sometimes spangled with scales of mica or rendered opaline by means of asbestus. Flint or chert are often colored by mixture with the material of the enclosing rock.

Diff. Quartz is exceedingly various in color and form, but may be distinguished, by (1) absence of true cleavage; (2) its hardness; (3) its infusibility before the blowpipe; (4) its insolubility with either of the common acids; (5) its effervescence when heated B.B. with soda; and (6) when crystallized, by the forms of its crystals, which are almost always six-sided prisms terminating in six-sided pyramids.

The varieties of quartz owe their peculiarities either to crystallization, mode of formation, or impurities, and they fall naturally into three series.

I. The *vitreous varieties,* distinguished by their glassy fracture.

II. The *chalcedonic varieties,* having a subvitreous or a waxy lustre, and generally translucent.

III. The *jaspery cryptocrystalline varieties,* having barely a glimmering lustre or none, and opaque.

I. VITREOUS VARIETIES.

Rock Crystal. Pure pellucid quartz. G. = 2·65.

To this mineral the word *crystal* was first applied by the ancients; it is from the Greek *krustallos,* meaning *ice.* The pure specimens are often cut and used in jewelry, under the name of "white stone." It is also used for optical instruments and spectacle-glasses. Even in ancient times it was made into cups and vases. Nero is said to have dashed to pieces two cups of this kind on hearing of the revolt that caused his ruin, one of which cost him a sum equal to $3000.

Amethyst. Purple or bluish-violet, and often of great beauty. It was called amethyst on account of its supposed preservative powers against intoxication. When finely and uniformly colored, highly esteemed as a gem. G. = 2·65–2·66.

Rose Quartz. Pink or rose-colored. Seldom occurs in crystals; generally in masses much fractured, and imperfectly transparent. The color fades on exposure to the light, and on this account it is little used as an ornamental stone, yet is sometimes cut into cups and vases. G. = 2·65.

False Topaz. Light yellow pellucid crystals. Often cut and set for topaz. Absence of cleavage distinguishes it from true topaz. The name *citrine*, often applied to this variety, alludes to its yellow color.

Smoky Quartz. Crystals of a smoky tint; the color is sometimes so dark as to be nearly black and opaque except in splinters. It is the *cairngorm* stone. G. = 2·65–2·66.

Milky Quartz. Milk-white, nearly opaque, massive, and of common occurrence. Has often a greasy lustre, and is then called *greasy quartz.* G. = 2·64–2 66.

Prase. Leek-green, massive; resembling some shades of beryl in tint, but easily distinguished by the absence of cleavage and its infusibility.

Aventurine Quartz. Common quartz spangled throughout with scales of golden-yellow mica. Usually translucent, and gray, brown, or reddish brown in color.

Ferruginous Quartz. Opaque, and either of yellow, brownish-yellow, or red color, from the presence of iron oxide.

II. CHALCEDONIC VARIETIES.

Chalcedony. Translucent, massive, with a glistening and somewhat waxy lustre; usually of a pale grayish, bluish, whitish, or light brownish shade. Often occurs lining or filling cavities in amygdaloidal and other rocks. The cavities are little caverns into which siliceous waters have, at some period, filtrated and deposited their silica. The stalactites of chalcedony were pendants from the roof of the cavity. Some of these chalcedony grottos are several feet in diameter. Large geodes of this kind occur in the Keokuk limestone in Illinois and Iowa.

Chrysoprase. Apple-green chalcedony; colored by nickel.

Carnelian. Bright red chalcedony, of a clear, rich tint. Cut and polished and much used in the more common jewelry, and for seals and beads.

Sard. A deep brownish-red chalcedony, of a blood-red color by transmitted light.

Agate. A variegated chalcedony. The colors are distributed in clouds, spots, or concentric bands. These bands take straight, circular, or zigzag forms; and when the last, it is called *fortification agate*, so named from the resemblance to the angular outlines of a fortification. These bands are the edges of layers of chalcedony, and these layers are the successive deposits during the process of its formation. *Mocha stone* or *Moss agate* is a brownish agate, consisting of chalcedony with dendritic or moss-like delineations, of an opaque yellowish-brown color. All the varieties of agate are beautiful stones when polished, but are not much used in fine jewelry. The colors may be darkened by boiling the stone in oil, and then dropping it into sulphuric acid; a little oil is absorbed by some of the layers, which becomes blackened or charred by the acid. Agates are sometimes artificially colored blue and of other shades.

Onyx. A kind of agate having the colors arranged in flat horizontal layers; the colors are usually light clear brown and an opaque white. When the stone consists of sard and white chalcedony in alternate layers, it is called *sardonyx*. Onyx is the material used for cameos, and is well fitted for this kind of miniature sculpture. The figure is carved out of one layer and stands in relief on another. A noted ancient cameo is the Mantuan vase at Brunswick. It was cut from a single stone, and has the form of a cream-pot, about 7 inches high and 2½ broad. On its outside, which is of a brown color, there are white and yellow groups of raised figures, representing Ceres and Triptolemus in search of Proserpine.

Cat's Eye. Greenish-gray translucent chalcedony, having a peculiar opalescence, or glaring internal reflections, like the eye of a cat, when cut with a spheroidal surface. The effect is owing to filaments of asbestus. It comes from Ceylon and Malabar, ready cut and polished, and is a gem of considerable value. Other hard minerals having similar opalescence are included under the name.

Flint, Hornstone, Chert. Massive compact silica, of dark

shades of smoky gray, brown, or even black, feebly translucent, breaking with sharp cutting edges and a conchoidal surface. Flint occurs in nodules in chalk; not unfrequently the nodules are in part chalcedonic. Hornstone differs from flint in being more brittle, but is essentially the same thing; it is often found in common limestone. *Chert* is an impure hornstone. Limestones containing hornstone or chert are often called *cherty* limestone.

Plasma. A faintly translucent variety of chalcedony approaching jasper, of a green color, sprinkled with yellow and whitish dots.

III. JASPERY VARIETIES.

Jasper. A dull opaque red, yellow, or brownish siliceous rock. It also occurs of green and other shades. *Riband jasper* is a jasper consisting of broad stripes of green, yellow, gray, red, or brown. *Egyptian jasper* consists of these colors in irregular concentric zones, and occurs in nodules, which are often cut across and polished. *Ruin jasper* is a variety with delineations like ruins, of some brownish or yellowish shade on a darker ground. *Porcelain jasper* is nothing but a baked clay, and differs from jasper in being fusible before the blowpipe. Red felsyte resembles red jasper; but this is also fusible, and consists largely of feldspar.

Jasper admits of a high polish, and is a handsome stone for inlaid work, but is not much used as a gem.

Bloodstone or *Heliotrope.* Deep green, slightly translucent, containing spots of red, which have some resemblance to drops of blood. Contains a few per cent. of clay and iron oxide mechanically combined with the silica. The red spots are colored with iron. There is a bust of Christ in the royal collection at Paris, cut in this stone, in which the red spots are so managed as to represent drops of blood.

Lydian Stone, Touchstone, Basanite. Velvet-black and opaque, and used, on account of its hardness and black color, for trying the purity of the precious metals; this is done by comparing the color of the mark left on it with that of an alloy of known character. The effect of acids upon the mark is also noted.

Besides the above there are other varieties arising from structure.

Tabular Quartz. Consists of thin plates, either parallel or crossing one another and leaving large open-cells.

Granular Quartz. A rock consisting of quartz grains compactly cemented. The colors are white, gray, flesh-red, yellowish, or reddish brown. It is a hard siliceous sandstone. Ordinary sandstone often consists of nearly pure quartz.

Pseudomorphous Quartz. Quartz under the forms of calcite, barite, fluorite, or other mineral. Shells, corals, etc., are sometimes found converted into quartz by the ordinary process of petrifaction.

Silicified Wood. Petrified wood often consists of quartz, quartz having taken the place of the original wood. In some specimens the wood is converted into chalcedony and agate of various colors, having great beauty when polished.

Quartz with penetrating crystallizations. The kinds are as numerous as the kinds of penetrating minerals. Rutile, asbestus, actinolite, and tourmaline sometimes occur in capillary or acicular forms, and give a specimen much interest. The delicate needles of rutile, in such cases, must have existed in the rock cavity attached to its sides by one or both ends, and the quartz afterward became deposited about them; cut specimens sometimes used in jewelry are called in French *Flèches d'amour.*

Obs. Quartz is a constituent of granite, gneiss, mica schist, and many other common rocks, and the chief or only constituent of many sandstones, and of the sands of most sea-shores Fine quartz crystals occur in Herkimer Co., New York, at Middlefield, Little Falls, Salisbury, and Newport, in the soil and in cavities in a sandstone. The beds of iron ore at Fowler and Hermon, St. Lawrence Co., afford dodecahedral crystals. Diamond Island, Lake George, Pelham, and Chesterfield, Mass.; Paris and Perry, Me.; Meadow Mt., Md.; and Hot Springs, Arkansas, are other localities. *Rose quartz* is found at Albany, Paris, Stow, Me.; Acworth, N. H.; and Southbury, Ct. *Smoky quartz* at Goshen, Mass.; Paris, Me.; in Burke and Alexander Cos., N. Carolina; at Pike's Peak, Col. (whence it is largely exported); and elsewhere. *Amethyst* at Bristol, R. I.; Delaware and Chester Cos., Pa.; Keweenaw Point, Lake Superior; Clayton, Rabun Co., Ga.; in Arizona; Nevada. *Chalcedony* and *agates* in Nova Scotia, poor near Northampton, and along the trap of the Connecticut

Valley—finer near Lake Superior, upon some of the Western rivers, and in Oregon. *Chrysoprase* occurs at Belmont's lead-mine, St. Lawrence Co., N. Y., and a green quartz (often called chrysoprase) at New Fane, Vt., along with fine drusy quartz. *Heliotrope* occupies veins in slate at Bloomingrove, Orange County, N. Y. *Silicified wood*, much of it agatized, abundant near Holbrook, Arizona (whence it is now procured for polishing), California, Colorado, Valley of the Yellowstone, etc.

Switzerland, Dauphiny, Piedmont, the Carrara quarries, and numerous other foreign localities furnish fine crystals.

The silica of the feldspars, owing to the alkali present with it—either potash, soda, or lime—is easily dissolved by hot waters (those of geysers and hot springs), and a solution of alkaline silicate is thus made, much like the soda-silicate of the shops called *soluble silica* or *water-glass*. From such solutions quartz has been deposited extensively in the rocks of the globe, in fissures making quartz veins; in cavities small and large, making geodes of chalcedony, agate, or of quartz crystals, or filling the cavities solid; or silicifying wood. Some porous kinds of igneous rocks or lavas (trachytes and allied kinds), and especially the beds made of volcanic débris or tufas, undergo alteration easily through the action of percolating waters, and little heat is required for it; and where volcanic débris (ashes, scoria) have covered forests, the trees of the forests have been silicified over large areas, as in California, Arizona, and Nevada. The feldspar in the change is converted into kaolin, and in the process a fourth to a third of the silica is set free; besides, pyroxene or hornblende, if present, loses also as large a part of the silica; consequently the supply of discharged silica is very large. The liberated silica, besides making quartz, often makes *opal*, another form of silica; and this is the chief source of opal. It often produces, also, by combination with the alumina and other bases at hand, various silicates in the cavities or fissures of the rocks, like the zeolites—minerals usually found in the cavities of igneous rocks.

Opal.

Compact and amorphous, texture colloid; also in reniform and stalactitic shapes; also earthy. Colors white, yellow, red, brown, green, blue, and gray. The finest

varieties exhibit from within, when turned in the hand, a rich play of colors of delicate shades. Lustre waxy to subvitreous. H. = 5·5–6·5. G. = 1·9–2·3.

Composition. Consists of silica, like quartz; but of silica in a different molecular state, the hardness and specific gravity being less; and it being soluble in a strong alkaline solution, especially if heated. Usually contains a few per cent. of water—amounting in some kinds to 12 per cent.; but the water is not generally regarded as an essential constituent. Differs from quartz also in its lustre, which is more waxy than chalcedony; also in the total absence of a crystalline texture.

VARIETIES.

Precious Opal. External color usually milky, but having within a rich play of delicate tints; a gem of rare beauty. A large mass in the imperial cabinet of Vienna weighs seventeen ounces, and is nearly as large as a man's fist, but contains numerous fissures and is not entirely disengaged from the matrix. This stone was well known to the ancients and highly valued by them. They called it *Paideros*, or *Child Beautiful as Love.* The noble opal is found near Cashau in Hungary, and in Honduras, South America; also on the Faroe Islands; at Esperanza, in Mexico.

Fire Opal, Girasol. An opal with yellow and bright hyacinth or fire-red reflections. It comes from Mexico and the Faroe Islands; Washington Co., Ga. A beautiful blue opal occurs in Queensland, Australia.

Common Opal, Semiopal. Has the hardness of opal, its waxy or resinous lustre, but no colored reflections from within, though sometimes a milky opalescence. The colors are white, gray, red, yellow, bluish, greenish to dark grayish-green. Translucent to nearly opaque. Occurs with some of the silicified wood of Arizona, etc., but much of it retains some of the structure of the wood, and is *wood-opal.*

Hydrophane. Opaque white or yellowish when dry, but translucent and opalescent after immersion in water.

Cacholong. Opaque white, or bluish white; usually associated with chalcedony. Part so called is chalcedony; other specimens contain water, and are allied to hydrophane. Contains also a little alumina and adheres to the tongue.

Hyalite, Muller's Glass. Glassy transparent; in small concretions, occasionally stalactitic. Resembles somewhat transparent gum-arabic. An analysis obtained Silica 92·00, water 6·33.

Menilite. Brown, opaque; compact reniform; occasionally slaty. *Composition*, Silica 85·5, water 11·0 (Klaproth). In slate at Menil Montant, near Paris.

Wood Opal. Gray, brown, or black, having the structure of wood, being wood petrified with hydrated silica (or opal), instead of quartz.

Opal Jasper. Resembles jasper in color, due to a little iron; but is resinous in lustre and not so hard.

Siliceous Sinter, Geyserite. A loose, porous siliceous rock, grayish to white in color; deposited around geysers, as those of Iceland and the Yellowstone Park, in cellular or compact masses, sometimes in stalactitic or cauliflower-like shapes. *Viandite* is an unusually hydrous variety, a leathery incrustation which crumbles on drying: from the Yellowstone Park. *Pearl sinter*, or *Fiorite*, occurs in volcanic tufa in smooth and shining globular, botryoidal masses, having a pearly lustre.

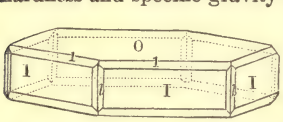
Float Stone. A variety of opal having a porous and fibrous texture, and hence so light that it will float on water. It occurs in concretionary or tuberose masses, which often have a nucleus of quartz.

Tripolite (*Diatomite, Infusorial Earth*). A white or grayish-white earth, massive, laminated, or slaty, made mainly of siliceous secretions of microscopic plants called Diatoms, with more or less of the spicules of sponges. Forms beds of considerable extent, and often occurs beneath peat (because diatoms lived in the waters of the shallow pond before it became a drying marsh); as in Maine, New Hampshire, Nevada, California. It is sold as a polishing powder under the name of *electrosilicon*. Dynamite was formerly made by mixing nitroglycerine (liquid) with it, but woodpulp is now used instead. It is used for making solutions of soluble silica (soda silicate), for purposes of a cement. Owing to its poor conduction of heat, it has been applied as a protection to steam boilers and pipes.

Tabasheer is a siliceous aggregation found in the joints of the bamboo in India, and not properly a mineral. Contains several per cent. of water, and has nearly the appearance of hyalite.

Diff. Infusibility before the blowpipe is the best character for distinguishing opal from pitchstone, pearlstone, and other species it resembles. The absence of anything like cleavage or crystalline structure is another characteristic. Its inferior hardness, specific gravity, and resinous or greasy lustre, separate it from quartz.

Tridymite. Pure silica, like quartz and opal, with very nearly the hardness and specific gravity of opal, but occurring in tabular hexagonal prisms, $1 \wedge 1 = 127° 35'$ over a pyramidal edge and 124° 3′ over *I*. If not crystallized opal, it is a *third* state of SiO_2. In trachytic and some other volcanic rocks in Germany; island Vulcano; Mexico; Yellowstone Park; Colorado, etc. *Asmanite* is the same from meteorites.



Jenzschite. Silica, SiO_2, in, it is supposed, a *fourth* state, it resembling opal in aspect and in solubility in alkaline solutions, but having the specific gravity of quartz, or 2·6. Hüttenberg, Carinthia; near Weissig; Regensberg; Brazil.

Melanophlogite. Colorless cubes (pseudomorphs ?) consisting of silica, with a little sulphur trioxide and water. On Sulphur, Sicily.

Proidonite. Silicon fluoride. Observed as an exhalation at Vesuvius in 1872. *Hieratite;* $2KF + SiF_4$, Vulcano.

2. SILICATES.

The Silicates are here divided into the *Anhydrous* and the *Hydrous.*

In part of the Anhydrous Silicates, the combining value or quantivalence (see page 88) of the silicon is to that of the basic elements as 2 to 1; in another part, as 1 to 1; and in a third division, as less-than-1 to 1. On this ground the mineral silicates are here arranged in three groups, named respectively: I. BISILICATES; II. UNISILICATES; and III. SUBSILICATES.

In the *Bisilicates,* one molecule of silicon is combined with *one* molecule of an element in the protoxide state, as Mg, Ca, Fe, etc., or one third of a molecule of an element in the sesquioxide state, as Al, Fe, Mn, etc.; or, what is the same thing, 3 molecules of silicon, with 3 of an element in the protoxide state, or 1 of an element in the sesquioxide state. The general formulas of such compounds is hence RO_2Si, or $R\dot{R}O_2Si_2$, or, if elements in both the protoxide and sesquioxide state are present, $(R_3\dot{R})O_2Si_2$, as explained on page 91.

In the *Unisilicates*, one molecule of silicon is combined with two of an element in the protoxide state, that is, for example, Mg_2, Ca_2, Fe_2; or with two thirds of a molecule in the sesquioxide state, that is, two thirds of Al, Fe, Mn. The formula of these silicates is hence R_2O_4Si, or $R^{\frac{2}{3}}_2O_4Si$, or, in order to remove the fraction in the last, $R_2O_{12}Si_3$; which becomes, when elements in the protoxide and sesquioxide state are both present, $(R_3, R)_2O_{12}Si_3$.

Among the species referred to the Unisilicates there are some that vary from the unisilicate ratio. This occurs especially in species in which an alkali is present, as in the Feldspars, Micas, and Scapolites.

The *Subsilicates* vary in the proportion of the silicon to the basic elements, and graduate into the Unisilicates.

The same three grand divisions exist more or less satisfactorily among the Hydrous Silicates.

Some hydrous silicates give evidence, by holding to the water when highly heated, that the water is basic (that is, its hydrogen replaces the metal of other oxides among the bases); and these, therefore, are here arranged with the anhydrous species. Some examples are epidote, zoisite, and euclase.

Specimens of the anhydrous silicates often contain 2 or 3 p. c. of water as a consequence of incipient alteration.

A. ANHYDROUS SILICATES.

I. BISILICATES.

The bisilicates, when the base is in the protoxide state and have hence the general formula RO_3Si, are resolved *in analyses* into protoxides and silica in the ratio of $1RO$ to $1SiO_2$, in which, as the term *bisilicate* implies, the oxygen of the silica is twice that of the protoxides. If the base is in both the protoxide and sesquioxide states, giving the formula $(R_3, R)\ O_3Si_3$, the mineral is resolved in analyses into protoxides, sesquioxides, and silica. If the ratio of the protoxides to sesquioxides is 1 : 1, the formula will become $\frac{1}{2}R_3\frac{1}{2}RO_9Si_3$ which, doubled, to clear it of the fractions, becomes $R_3RO_{18}Si_6$; and analyses give then for the oxides and silica $3RO$, $1R_2O_3$, $6SiO_2$.

Among the following Bisilicates the species from enstatite to spodumene and amphibole make a natural group called the hornblende, or hornblende and pyroxene group. They are closely related in composition and also in crystallization. The cleavage prism is rhombic, and has either an angle of about 124½° or of about 87°; and the former of these two rhombic prisms has just twice the breadth of the other; that is, if the lateral axis from the front to the back edge in each be taken as unity, the other lateral axis is twice as long in the prism of 124½° as it is in that of 87° 5′. The forms are either orthorhombic, monoclinic, or triclinic; and yet close relations in angles, as just stated, exist between them. Enstatite is a magnesium or magnesium and iron species; wollastonite, a calcium species; rhodonite, a manganese species; pyroxene and hornblende contain calcium with magnesium or iron; spodumene contains lithium and aluminium, aluminium replacing elements that in other species are in the protoxide state.

Enstatite.—Bronzite.

Orthorhombic; $I \wedge I = 88°\ 16'$. Prismatic cleavage easy. Usually possesses a fibrous appearance on the cleavage surface. Also massive and lamellar.

Color, grayish, yellowish or greenish white, or brown. Lustre pearly; often metalloidal in the bronzite variety. H. 5·5. G. 3·1–3·3.

Composition. MgO_3Si = Silica 60, magnesia 40. B.B. infusible, and insoluble. *Bronzite* has a portion of the magnesium replaced by iron.

Diff. Resembles amphibole and pyroxene, but is infusible, and orthorhombic in crystallization.

Obs. Occurs in the Vosges; Moravia; Bavaria; Baste, in the Hartz; Brewster's, N. Y.; Leiperville, Texas, Marple, Radnor's, Pa.; Bare Hills, Md.

Hypersthene. Near bronzite in form and composition, but contains a larger percentage of iron and B.B. fuses; on charcoal, becomes magnetic. St. Paul's Island, in Labrador; Isle of Skye; Greenland; Norway, etc. *Szaboite* is hypersthene; *Amblystegite* contains still more iron; *Diaclasite* is near bronzite.

Wollastonite.—Tabular Spar.

Monoclinic; $I \wedge I = 87° 28'$, $C = 69° 48'$. Rarely in oblique flattened prisms; usually massive. Cleaves easily in one direction, affording a lined or indistinctly columnar surface. Usually white, but sometimes tinged with yellow, red, or brown. Translucent, or rarely subtransparent. Lustre vitreous, pearly. Brittle. H. = 4·5–5. G. = 2·85-2·91.

Composition. CaO_3Si = Silica 52, lime 48 = 100. B.B. fuses with difficulty to a subtransparent, colorless glass; in powder decomposed by hydrochloric acid, and the solution gelatinizes on evaporation; often effervesces when treated with acid on account of the presence of calcite.

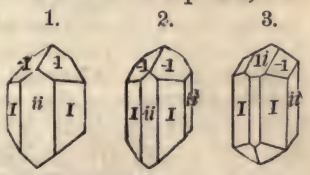
Diff. Differs from asbestus and tremolite in its more vitreous appearance and fracture, and by its gelatinizing in acid; from the zeolites by the absence of water, which all zeolites give in a closed tube; from feldspar in the fibrous appearance of a cleavage surface and the action of acids.

Obs. Usually found in granite or granular limestone; occasionally in basalt or lava. Occurs in Ireland at Dunmore Head; at Vesuvius and Capo di Bove; in the Hartz; Hungary; Sweden; Finland; Norway.

At Willsboro', Lewis, Diana, and Roger's Rock, N. Y., of a white color, along with garnet; at Boonville, in bowlders with garnet and pyroxene; Grenville, Canada; in Bucks Co., Pa.; at Keweenaw Point, L. Superior. *Edelforsite* is impure wollastonite.

Pyroxene.—Augite.

Monoclinic. $I \wedge I = 87° 5'$, $C = 73° 59' = O \wedge i\text{-}i$. Cleavage perfect parallel with the sides of this prism, and often distinct parallel with the diagonals. Usually in thick and stout prisms, of 4, 6, or 8 sides, terminating in two faces meeting at an edge. $I \wedge i\text{-}i = 133° 33'$, $I \wedge i\text{-}\bar{i} = 136° 27'$; $\text{-}1 \wedge \text{-}1 = 131° 24'$. Often twinned parallel to $i\text{-}i$; also often lamellar parallel to O, owing to the interposition of twinning lamellæ. Massive varieties



of a coarse lamellar structure; also fibrous, fibres often very fine and often long capillary. Also granular; usually coarse granular and friable; grains usually angular, sometimes round. Also compact massive.

Colors green of various shades, verging to white on one side and brown and black on the other, passing through *blue* shades, but *not yellow*. Lustre vitreous, inclining to resinous or pearly; the latter in fibrous varieties. Transparent to opaque. H. = 5–6. G. = 3·2–3·5.

Composition. RO_3Si (or $RO + SiO_2$); in which R may be Ca, Mg, Fe, Mn, and sometimes Zn, K_2, Na_2, these bases replacing one another without changing the crystalline form, of which two or more are usually present; the first three are most common. Calcium is always present. The following is an analysis of a typical variety: Silica 55·0, lime 23·5, magnesia 16·5, manganese protoxide ·5, iron protoxide 4·5 = 100. Fuses B.B., but the fusibility varies with the composition, and the ferriferous varieties are most fusible. Insoluble in acids.

Diff. The crystalline form, and ready cleavage in two planes nearly at right angles to one another (87° 5′), are the best characters for its determination.

Varieties.—The varieties may be divided into three sections—the light colored, the dark colored, and the thin foliated.

I. *Malacolite* or *white augite*, a calcium-magnesium pyroxene, including white or grayish white crystals or crystalline masses. *Diopside*, of the same composition, in greenish white or grayish green crystals, and cleavable masses cleaving with a bright smooth surface. *Sahlite*, containing iron in addition, and of a more dingy green color, with less lustre and a coarser structure than diopside, but otherwise similar; named from the place Sala, where it occurs. *Fassaite*, containing a little alumina in addition to the elements of sahlite, and found in crystals of rich green shades and smooth and lustrous exterior; named from the foreign locality, Fassa. *Coccolite*, coarsely granular, named from the Greek *coccos*, grain; when green, called *green coccolite;* white, *white coccolite*. The specific gravity of these varieties varies from 3·25 to 3·3.

Asbestus. Includes *fibrous* varieties of both pyroxene and hornblende; it is more particularly noticed beyond, under the latter species, as pyroxene is rarely asbestiform.

II. *Augite.* The black and greenish black crystals, which contain a larger percentage of iron, or iron and magnesium, and which mostly present the form in figure 1. Specific gravity 3·3–3·4. This is the common pyroxene of eruptive rocks. *Hedenbergite,* an iron-calcium pyroxene, a greenish black opaque variety, in cleavable masses affording a greenish brown streak; specific gravity 3·5. *Manganhedenbergite,* near the last, contains 6 to 7 p. c. of manganese protoxide; G. = 3·55. *Polylite, Hudsonite,* and *Jeffersonite* fall here; the last contains some zinc oxide. These varieties fuse more easily than the preceding, and the globule obtained is colored black by the iron oxide.

III. *Diallage,* a thin-foliated variety, often occurring imbedded in serpentine and some other rocks. Differs from bronzite and hypersthene in crystallization, and in being more fusible; the foliation is often a result of incipient alteration, p. 450.

Obs. Pyroxene is one of the most common minerals. It is a constituent in almost all basic eruptive rocks, like basalt, and is frequently met with in rocks of other kinds; a white kind is common in granular limestone, and also a green. In basalt or lavas the crystals are generally small and black or greenish black. In other rocks it occurs of all the shades of color given, and the crystals of all sizes to a foot or more in length. One crystal from Orange County, measured 6 inches in length, and 10 in circumference. White crystals occur at Canaan, Ct.; Sheffield, Monterey, Mass.; Kingsbridge, New York County, and the Sing Sing quarries, Westchester Co., N. Y.; in Orange Co. at several localities; green crystals at Trumbull, Ct., at various places in Orange Co., N. Y., Roger's Rock and other localities in Essex, Lewis, and St. Lawrence Cos. Dark green or black crystals are met with near Edenville, N. Y., Diana, Lewis Co. Large crystals occur with the apatite of Renfrew, Canada. Jeffersonite occurs at Franklin, in N. J. Green coccolite is found at Roger's Rock, Long Pond, and Willsboro', N. Y.; black coccolite, in the forest of Dean, Orange Co., N. Y. Diopside, at Raymond and Rumford, Me.; Hustis's farm, Phillipstown, and De Kalb, N. Y.; Fort Defiance, Ariz.; Gallup, N. Mex.

Pyroxene was thus named by *Haüy* from the Greek *pur,* fire, and *xenos,* stranger, in allusion to its occurring in

lavas, where Haüy thought it did not belong, or was a guest. The name *Augite* is from the Greek *auge*, lustre.

Ægirite. Black to greenish black in color. A pyroxene containing nearly 10 per cent. of soda, and much iron sesquioxide. Near Brevig in Norway; Hot Springs, Arkansas.

Acmite. In long highly-polished prisms, of a dark brown or reddish brown color, with a pointed extremity. $I \wedge I = 86° 56'$, resembling pyroxene; contains over 12 per cent. of soda; B.B. fuses easily. In granite, near Kongsberg, Norway; in nepheline rock near Montreal.

Babingtonite. Resembles some varieties of pyroxene; crystals greenish black, splendent. In quartz, Arendal, Norway.

Uralite. Has the form of pyroxene but cleavage of hornblende; and has been produced through the alteration of pyroxene to hornblende. Some Archæan and igneous rocks that are now hornblendic were originally pyroxene rocks.

Rhodonite.—Manganese Spar, Fowlerite.

Triclinic, but nearly isomorphous with pyroxene. Also massive.

Color reddish, commonly deep flesh-red; also brownish, greenish, or yellowish, when impure; very often black on the surface; streak uncolored. Lustre vitreous. Transparent to opaque. Becomes black on exposure. H. = 5·5–6·5. G. = 3·4–3·7.

Composition. MnO_3Si = Silica 45·9, manganese protoxide 54·1 = 100. It commonly contains a little iron and lime replacing the manganese. Becomes dark brown when heated; with borax in the outer flame, gives a deep violet color to the bead while hot, a red-brown when cold. A variety containing a little zinc, from Franklin Furnace, N. J., has been named *Keatingine.*

Diff. Resembles somewhat a flesh-red feldspar, but differs in greater specific gravity, in blackening on exposure, and in the glass with borax.

Obs. Occurs in Sweden, the Hartz, Siberia, and elsewhere. In the United States it is found at Blue Hill Bay, Me.; Plainfield and Cummington, Mass.; abundantly at Hinsdale, and on Stony Mountain, near Winchester, N. H.; in crystals at Franklin Furnace, N. J.; at Alice Mine, Butte City, Montana. The black exterior is a more or less pure hydrated oxide of manganese, produced by oxidation. A hydrous rhodonite has been called *Hydro-rhodonite.*

Rhodonite may be used in making a violet-colored glass,

and also for a colored glazing on stoneware. It receives a high polish and is sometimes employed for inlaid work.

Spodumene.

Monoclinic. $I \wedge I = 87°$, $C = 69° 40'$, being near pyroxene. Cleavage easy, parallel to I and i-i. Surface of cleavage pearly. Color grayish or greenish; pale amethystine; rarely emerald-green. Lustre of cleavage surface pearly. Translucent to subtranslucent. H. = 6·5–7. G. = 3·15–3·19.

Composition. $(R_2, Al)O_3Si_2$, in which R equals Li_2, and $3Li_2$ is to Al as 1 : 3; this corresponds to $Li_2Al_2O_{12}Si_4$ = Silica 64·9, alumina 27·6, lithia 7·5 = 100. B.B. becomes white and opaque, fuses, swells up, and imparts to the flame the purple-red flame of lithia. Unaffected by acids.

Diff. Resembles feldspar and scapolite, but has a higher specific gravity and a more pearly lustre, and affords rhombic prisms by easy cleavage. The lithia reaction is its most characteristic test.

Obs. Occurs in granite at Goshen, Chesterfield, Norwich, and Sterling, Mass.; at Windham, Me.; at Brookfield and Branchville, Ct.; at Stony Point, Alexander Co., N. C., an emerald-green variety (*Hiddenite*) rivalling the emerald as a gem; 2 m. from Harney, Black Hills, Dak.; at Utö, in Sweden; Sterzing in the Tyrol; and at Killiney Bay, near Dublin. Some crystals from Branchville, Goshen, and the Black Hills a yard or more long. *Cymatolite* (a mixture of albite and muscovite), *Killinite, muscovite, albite, microcline, eucryptite,* are among the results of its alteration at Branchville.

This mineral is remarkable for the *lithia* it contains.

Petalite.

Monoclinic. In imperfectly cleavable masses; most prominent cleavage angle 141° 30′. Color white, gray, pale reddish, greenish. Lustre vitreous to sub-pearly. Translucent. H. = 6–6·5. G. = 2·5.

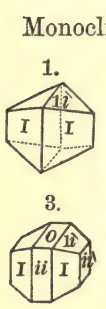
Composition. Contains lithia, like spodumene, and affords Silica 77·9, alumina 17·7, lithia 3·1, soda 1·3 = 100. Phosphoresces when gently heated. Fuses with difficulty on the edges. Reacts for lithia.

Diff. Like spodumene in the lithia reaction, but unlike it in lustre, specific gravity, and greater fusibility.

Obs. From Utö, Sweden; also from Elba (*Castor* or *Castorite*). An alteration product of castor has been called *Hydrocastorite.*

Amphibole.—Hornblende.

Monoclinic; $I \wedge I = 124° 30$, $C = 75° 2'$. Cleavage perfect parallel with *I*. Often in long, slender, flat rhombic prisms (Fig. 2), breaking easily transversely; also often in 6-sided prisms, with oblique extremities. Frequently columnar, with a bladed structure; long fibrous or asbestiform, the fibres coarse or fine, often like flax, and pearly or silky; also lamellar; also granular, either coarse or fine.



Colors white to black, passing through bluish green, grayish green, green, and brownish green shades, to black. Lustre vitreous, with the cleavage face inclining to pearly; fibrous varieties silky. Nearly transparent to opaque. H. = 5–6. G. = 2·9–3·4.

Composition. RO_3Si (or $RO + SiO_2$), as for pyroxene. R may correspond to two or more of the basic elements Mg, Ca, Fe, Mn, Na_2, K_2, the first three being most common. Aluminium often replaces a portion of the silicon. B.B. as in pyroxene; fuses, but the fusibility varies indefinitely, being easiest in the black varieties.

Diff. Distinguished from pyroxene by the very ready cleavages parallel to a prism of $124\frac{1}{2}°$, and the prevalence of 6-sided prisms or sharp rhombic instead of 87° 5′.

This species, like pyroxene, has numerous varieties, differing much in external appearance, and arising from the same causes—isomorphism, and crystallization. The following are the most important:

I. LIGHT-COLORED VARIETIES.

Tremolite, Grammatite. White and grayish, in bladed crystallizations and long crystals penetrating the gangue or aggregated into coarse columnar forms. Sometimes nearly transparent. G. = 2·9. Formula $(Ca, Mg)O_3Si =$

Silica 57·70, magnesia 28·85, lime 13·45 = 100. Named from *Tremola*, in Switzerland, where it is not found.

Actinolite. Light green fibrous, columnar and prismatic, and massive; a magnesium-calcium-iron amphibole. *Glassy actinolite* includes the bright glassy, green crystals, usually long and slender, and penetrating the gangue like tremolite; *radiated*, olive-green masses, consisting of aggregations of coarse acicular fibres, radiating or divergent; *asbestiform*, resembles the radiated, but the fibres more delicate; G. = 3·0–3·1. Named *actinolite* from the Greek, *aktin*, a ray of the sun, referring to the frequent radiated structure.

Composition of glassy actinolite: Silica 59·75, magnesia 21·1, lime 14·25, iron protoxide 3·9, manganese protoxide 0·3, hydrofluoric acid 0·8 (Bonsdorf).

Asbestus. In slender fibres easily separable, and sometimes like flax. Either green or white. *Amianthus* includes fine silky varieties. (Much so called is serpentine; serpentine is hydrous, and is thereby easily distinguished.) *Ligniform asbestus* is compact and hard, brownish and yellowish in color, looking like petrified wood. *Mountain leather* occurs in thin, tough sheets, feeling a little like kid leather; consists of interlaced fibres of asbestus, and forms thin seams between layers or in fissures of rocks. *Mountain cork* is similar, but is in thicker masses; it has the elasticity of cork, and is usually white or grayish white. *Breislakite* is a wool-like variety from Vesuvius.

The preceding light-colored varieties contain little or no alumina or iron.

Nephrite. A tough compact variety, related to tremolite. Color light green or blue. Breaks with a splintery fracture and glistening lustre. H. = 6–6·5. G. = 3. A magnesium-calcium amphibole. Nephrite is made into images, and was formerly worn as a charm. It was supposed to be a cure for diseases of the kidney, whence the name, from the Greek, *nephros*, kidney. In New Zealand, China, and Western America it is carved by the inhabitants, or polished down into various fanciful shapes. It is called jade; but the aluminium-sodium silicate, called jadeite, is the stone most highly prized of all that pass under the name of jade. Part of the "jade" of China is prehnite.

II. DARK-COLORED VARIETIES

Cummingtonite. A magnesium-iron amphibole; color gray or brown; usually fibrous. Named from the locality where found, Cummington, Mass.

Pargasite. Dark green crystals, short and stout (resembling Fig. 4), with bright lustre, of which Pargas in Finland is a noted locality. G. = 3·11. *Composition:* Silica 45·5, alumina 14·9, iron protoxide 8·8, manganese protoxide 1·5, magnesia 14·4, lime 14·9 = 100.

Hornblende. Black and greenish black crystals and massive specimens. Often in slender crystallizations like actinolite; also short and stout like Figs. 4 and 5, the latter more especially. Contains a large percentage of iron oxide, and to this owes its dark color. A tough mineral especially when massive, as is implied in the name it bears. Pargasite and hornblende contain both alumina and iron. *Composition:* Silica 48·8, alumina 7·5, magnesia 13·6, lime 10·2, iron protoxide 18·8, manganese protoxide 1·1 = 100.

Bergamaskite. A variety containing no magnesia. From Bergamo.

Obs. An essential constituent of certain rocks, as syenyte, dioryte, and hornblende schist. Actinolite is usually found in magnesian rocks, as talc, steatite or serpentine; tremolite in crystalline dolomite; asbestus in the above rocks and also in serpentine. The pyroxene of some Archæan and igneous rocks has been found to be often changed throughout to hornblende (uralite). The two species differ in crystallization, and not in composition; and pyroxene is the less stable form of the two. See p. .

Black crystals of hornblende occur at Franconia, N. H., Chester, Mass.; Thomastown, Me.; Willsboro', N. Y.; Orange Co., N. Y.; and elsewhere. Pargasite, at Phippsburg and Parsonsfield, Me.; glassy actinolite, in steatite or talc, at Windham, Readsboro', and New Fane, Vt.; Middlefield and Blanford, Mass.; and radiated varieties at the same localities and many others. Tremolite and gray hornblende occur at Canaan, Ct.; Sheffield, Lee, Monterey, Mass.; Thomaston and Raymond, Me.; Dover, Kingsbridge, and New York Island, N. Y.; at Chestnut Hill, Pa.; at the Bare Hills, Md. Asbestus at many of the above localities; also Brighton and Sheffield, Mass.; Cotton Rock

and Hustis's farm, Phillipstown, N. Y.; Rabun and Fulton Cos., Ga. (where it is mined); Western N. Carolina; San Bernardino and San Diego and Calaveras Cos., Cal.; Province of Quebec, Canada (where it is mined, and is of excellent quality). Mountain leather is met with at Brunswick, N. J. *Edenite,* a white aluminous kind, occurs at Edenville, N. Y.

Asbestus is the only variety of this species used in the arts. The flax-like variety is sometimes woven into fire-proof textures. Its incombustibility and slow conduction of heat render it a complete protection against the flames. It is often made into gloves. A fabric when dirty need only be thrown into the fire for a few minutes to be white again. The ancients, who were acquainted with its properties, are said to have used it for napkins, on account of the ease with which it was cleaned. It was also the wick of the lamps in the ancient temples; and because it maintained a perpetual flame without being consumed, they named it *asbestos,* unconsumed. It is now used for the same purpose by the natives of Greenland. The name amianthus alludes to the ease of cleaning it, and is derived from *amiantos,* undefiled. Asbestus is extensively used for lining iron safes, and for protecting steam pipes and boilers. About 1600 tons of asbestus were used in the U. States in 1882; the average price $30 per ton. The Canadian is the best, and brings $25 to $90 to the ton. It is obtained also in Italy and Australia. The most of that used is serpentine.

Anthophyllite. Related in the angle of its prism to hornblende, but orthorhombic; in composition, and infusibility B.B., near bronzite; B.B. becomes magnetic. Kongsberg, Modum, Norway. *Silfbergite* is a manganesian variety of anthophyllite.

Kupfferite has the hornblende angle, but in composition is like enstatite, being a magnesian silicate.

Arfvedsonite. Near hornblende; but contains over 10 per cent. of soda, like acmite. Greenland; Norway; El Paso, Col.

Crocidolite. Near arfvedsonite in composition; lavender-blue to leek-green; fibrous. Orange River, South Africa; the Vosges; Rhode Island. Silicified crocidolite containing some limonite, now common in polished specimens, is called *tiger stone.*

Glaucophane. A bluish mineral with the amphibole angle. Island of Syra; Zermatt; N. Caledonia. *Wichtisite* may be the same species. *Gastaldite* is a related mineral from Aosta.

Milarite. Hexagonal; composition $(KH)Ca_2Al_2O_{32}Si_{12}$; being a quatersilicate instead of a bisilicate. Val Giuf, Graubünden (Grisons).

Beryl.—Emerald.

Hexagonal. In hexagonal prisms; *O* on 1 (plane on edge $O : I) = 150° 3'$. Cleavage basal, not very distinct. Rarely massive.

Color green, pale blue and yellow, emerald-green. Streak uncolored. Lustre vitreous; sometimes resinous. Transparent to sub-translucent. Brittle. H. = 7·5–8. G. = 2·67–2·75.

VARIETIES. The *emerald* is the rich green variety; it owes its color to the presence of chromium. *Beryl* includes the paler varieties, which are colored by iron. *Aquamarine* includes clear beryls of a sea-green, pale-bluish or bluish-green tint. *Golden emerald* has a rich yellow color.

Composition. $BeAl_3O_{18}Si_6$ with basic hydrogen in place of a sixth atomically of the beryllium. The beryl of Hebron afforded Silica 62·10, alumina 18·92, beryllium oxide 16·35, iron protoxide 0·47, cæsium oxide 2·93, soda 1·82, lithia 1·17, lime 0·35, water 2·33 =100·45. Other varieties fail of cæsium and lithium. *Emerald* contains less than one per cent. of chromium oxide. B.B. becomes clouded, but does not fuse; at a very high temperature the edges are rounded. Unacted upon by acids. *Rosterite* is a variety from Elba. *Pseudo-smaragdite* is altered beryl.

Diff. The hardness distinguishes this species from apatite; and this character, and also the form of the crystals, from green tourmaline.

Obs. Found in granite, gneiss, mica schist. Fine emeralds occur at Muso, near Santa Fé, in New Granada, in dolomite; one crystal, 2¼ in. long and about 2 in diameter, is in the cabinet of the Duke of Devonshire; another more splendid specimen, weighing only 6 oz., formerly in the possession of Mr. Hope, of London, cost £500. Emeralds of less beauty and great size occur in Siberia; one in the royal collection of Russia is 4½ inches in length and 12 in breadth, and weighs 16¾ pounds troy; another is 7 inches long and 4 broad, and weighs 6 pounds. Mount Zalora in Upper Egypt affords a less distinct variety. Some fine emeralds have been obtained at the Stony Point Mine, in Alexander Co., N. C.; one crystal was nearly 10 in. long.

The finest beryls (*aquamarines*) come from Siberia, Hindostan, and Brazil. One specimen belonging to Dom Pedro is as large as the head of a calf, and weighs 225 ounces, or more than 18½ pounds troy; it is transparent and without a flaw. In 1827 a fine aquamarine, weighing 35 grams, was found in Siberia, which is said to have been valued at 600,000 francs.

In the U. States beryls of enormous size have been obtained, but seldom transparent crystals. One hexagonal prism from Grafton, N. H., weighing 2900 lbs., 4 ft. long and 32 by 22 inches in its diameters, was of a bluish green color, with part of one extremity dull green and yellow. The finest crystals, some good for gems, have been found at Stoneham, Me.; also at Albany, Norway, Bethel, and elsewhere, Me.; fine at Royalston, Mass., formerly fine at Haddam, Ct.; also at Avondale mines, Delaware Co., Pa.; near Morgantown, and elsewhere, Burke Co., and Ray's Mine, Yancey Co., and elsewhere, N. C. Other localities are Barre, Fitchburg, Goshen, Mass.; Wilmot, N. H.; Grafton, Vt.; Monroe, Portland, Ct.; Leiperville, Chester, Upper Providence, Middletown, Concord, Marple, Pa.

Phenacite. A rhombohedral beryllium silicate, in colorless and yellowish crystals, with H. = 7·5–8 and G. = 3. The Urals; Switzerland; Durango, Mexico; Pike's Peak, Col., one 3 in. across; Florissant topaz loc. Col.

Bertrandite is related to phenacite in composition. It is orthorhombic, with $I \wedge I = 121° 20'$; colorless or yellowish; G. = 2·59. From near Nantes, France.

Eudialyte. Pale rose-red, crystals of rhombohedral form, containing 15·6 per cent. of zirconia. From West Greenland. *Eucolite* of Norway is here included.

Pollucite. Isometric. White, with vitreous lustre, and G. = 2·868. A *cæsium* silicate. Analysis afforded Rammelsberg Silica 48·15, alumina 16·31, potash 0·47, soda 2·48, cæsium oxide 30·00, water 2·59 = 100, giving very nearly the bisilicate formula $H_2Cs_2Al_2O_{15}Si_5$. Elba.

Cappelenite. Yttrium silico-borate; hexagonal; brown; G. = 4·4. Norway.

II. UNISILICATES.

For the convenience of the student, the general formulas of the regular Unisilicates are here re-stated. They are as follows:

If the base is in the protoxide state alone, the formula is R_2O_2Si (= $2RO + SiO_2$), in which R stands for Ca, Mg, Fe,

Mn, K_2, Na_2, or Li_2, or other mutually replaceable base. In analyses, the mineral is resolved into protoxides and silica, in the ratio of 2RO to SiO_2, in which the oxygen of the silica equals that of the basic portion.

If the base is in the sesquioxide state alone, the formula is $\dot{R}_2O_{12}Si_3$ ($=2\dot{R}O_3 + 3SiO_2$), in which $\dot{R}$ may stand for Al, Fe, or Mn, etc. Here the mineral is resolved, in analyses, into sesquioxides and silica in the ratio of $2\dot{R}O_3$ to $3SiO_2$, in which the oxygen of the silica again equals that of the basic portion.

If the basic portion is partly in the protoxide state and partly in the sesquioxide, the formula, in its most general form, is $(R_3, \dot{R})_2O_{12}Si_3$. In this formula the ratio of R_3 to $\dot{R}$ is not stated. If the ratio is 1 : 1, the formula becomes $R_3\dot{R}O_{12}Si_3$, or its equivalent $(\frac{1}{2}R_3\frac{1}{2}\dot{R})_2O_{12}Si_3$. In a case like this last, the mineral is resolved, in analyses, into protoxides, sesquioxides, and silica, in the ratio of $3RO : \dot{R}O_3 : 3SiO_2$, in which again the oxygen of the bases equals that of the silica.

If the proportion of R_3 to $\dot{R}$ is 1 : 3, this corresponds to $\frac{1}{3}R_3 : \dot{R}$, or, its equivalent, $R : \dot{R}$; and hence the formula in its general form will be $R\dot{R}O_8Si_2$.

If the base is in the dioxide state, the formula becomes RO_4Si ($= RO_2 + SiO_2$), an example of which occurs in zircon, whose formula is ZrO_4Si.

There are several natural groups of species among the Unisilicates.

GROUP.	STATE OF BASES.	CRYSTALLIZATION.
1. Chrysolite group,	protoxide,	Orthorhombic.
2. Willemite group,	protoxide,	Hexagonal.
3. Garnet group,	protoxide and sesquioxide,	Isometric.
4. Zircon group,	dioxide,	Tetragonal.
5. Idocrase and Scapolite groups,	protox. and sesquiox.	Tetragonal.
6. Mica group,	protox. and sesquiox.	Orthorhombic; plane angle of base, 120°; micaceous.
7. Feldspar group,	protox. and sesquiox.	Monoclinic or triclinic, $I \wedge I$ nearly 120°.

In the Scapolite, Mica, and Feldspar groups part of the species contain an alkali metal in the basic portion, and such kinds have generally an excess of silica. Among the feldspars, the species containing only calcium as the pro-

toxide base is a true unisilicate. In the others, there is an excess directly proportional to the increase of the soda, as explained beyond.

Chrysolite.—Olivine. Peridot.

Orthorhombic. In rectangular prisms having cleavage parallel with *i-ĭ*. Usually in imbedded grains of an olive-green color, looking like green bottle-glass; also yellowish green. Lustre vitreous. Transparent to translucent. H. = 6–7. G. = 3·3–3·6.

Composition. $(Mg, Fe)_2O_4Si$ (or $2\,(Mg, Fe)\,O + SiO_2$) =, for a common variety, Silica 41·39, magnesia 50·90, iron protoxide 7·71 = 100. The amount of iron is variable. B.B. whitens but is infusible; with borax, a yellow bead owing to the iron present. Decomposed by hydrochloric acid, and the solution gelatinizes when evaporated. *Hyalosiderite* is a very ferruginous variety which fuses B.B.

Diff. Distinguished from green quartz by its occurring disseminated in basaltic rocks, which never so occurs; and in its cleavage. From obsidian or volcanic glass it differs in its infusibility.

Obs. Occurs as a rock formation; also in a large part of the basalt of volcanic regions, and also in some andesyte, in various countries. As a rock it occurs in N. Carolina and Pennsylvania; and as a constituent of basalt in the eruptive regions of the Pacific slope, and sparingly in the trap (basalt) of New Jersey, New Hampshire, etc. *Boltonite*, from limestone at Bolton, Mass., is a variety of chrysolite. It also occurs in many meteorites.

Sometimes used as a gem, but too soft to be valued, and not delicate in its shade of color.

Forsterite is a magnesian chrysolite Mg_2O_4Si; *Fayalite*, an iron chrysolite, Fe_2O_4Si, and *fusible*, a rather common variety, occurring occasionally in crystals as in the obsidian of Yellowstone Park; *Monticellite*, a calcium-magnesium, $CaMg_2O_4Si$; *Hortonolite*, an iron-magnesium manganese chrysolite from Orange Co., N. Y.; *Rœpperite*, an iron-manganese-zinc chrysolite from Stirling Hill, N. J.; *Tephroite*, a manganese chrysolite, Mn_2O_4Si, from Stirling Hill, N. J.; *Knebelite*, a manganese-iron chrysolite, $MnFeO_4Si$, from Dannemora. *Igelströmite* (of M. Weibull) is near Knebelite. *Neochrysolite*, from Vesuvius, contains some manganese.

Cuspidite. In rose-red spear-shaped monoclinic crystals; H. = 5·6; G. = 2·85–2·86. Contains silica, lime, fluorine. From Vesuvius.

Leucophanite and *Meliphanite.* Contain the element beryllium; the

former, greenish yellow, and G. = 2·97; the latter, yellow and G. = 3·018. Norway.

Wöhlerite. Contains zirconium and also niobium; color light yellow; G. = 3·41.

Willemite. Zinc unisilicate, Zn_2O_4Si. See page 173.

Dioptase. Copper silicate, which, making the water basic, is a unisilicate, H_2CuO_4Si. See page 156. The Kirghese Steppes; Chili.

Friedelite. Rose-red manganese silicate, of the general formula R_7O_8Si, in which R consists of manganese and hydrogen in the atomic ratio 2 : 1. The Pyrenees.

Helvite (Helvin). Isometric; in tetrahedral crystals; color honey-yellow, brownish, greenish; lustre vitreo-resinous; H. = 6–6·5; G. = 3·1–3·3; contains manganese, iron and beryllium, and some sulphur. Saxony; Norway; Amelia Co., Va.

Danalite. Isometric; in octahedral crystals; color flesh-red to gray; lustre vitreo-resinous; H. = 5·5; G. = 3·427; contains zinc, beryllium, iron, manganese. Disseminated through granite at Rockport, Cape Ann, Mass.; near Gloucester, Mass.; Bartlett, N. H.

Eulytite. A bismuth silicate from Johanngeorgenstadt.

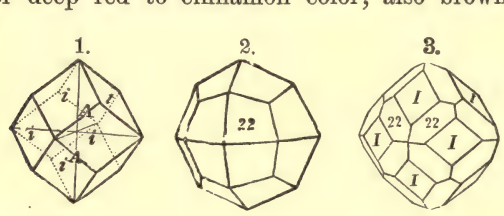
Bismuto-ferrite. A bismuth-iron silicate.

Peckhamite. In nodules in an Iowa meteorite.

Garnet.

Isometric. Dodecahedrons (Fig. 1) and trapezohedrons (Fig. 2); both forms are common, and are sometimes variously modified. Cleavage parallel to the faces of the dodecahedron sometimes rather distinct. Also found massive granular, and coarse lamellar.

Color deep red to cinnamon color; also brown, black,



green, emerald-green, rarely colorless. Transparent to opaque. Lustre vitreous. Brittle. H. = 6·5–7·5. G. = 3·1–4·3.

Composition and *Varieties.* General formula $R_3\dot{R}O_{12}Si_3$; in which R may be calcium, magnesium, iron, manganese, and $\dot{R}$ may be aluminium, iron, chromium. The varieties owe their differences to the proportions of these elements, or the substitution of one for another. Most garnets fuse easily B.B. to a brown or black glass; but the fusibility

varies, and chrome-garnet is infusible. Not decomposed by hydrochloric acid; but if first ignited, then pulverized and treated with acid, they are decomposed, and the solution usually gelatinizes when evaporated.

There are three series among the varieties: one, that of *alumina-garnet*, in which the sesquioxide base is chiefly aluminium; the second, that of *iron-garnet*, in which the sesquioxide base is chiefly iron instead of aluminium; and third, *chrome-garnet*, in which it is chromium.

I. ALUMINA-GARNET.

Almandite (*Almandine*). An iron alumina-garnet, $Fe_3Al_2O_{12}Si_3$ = Silica 36·1, alumina 20·6, iron protoxide 43·3 = 100. G. = 3·8–4·25. Of various shades of red, ruby-red, hyacinth-red, columbine-red, brownish red. If transparent, called *precious* garnet; if not so, *common* garnet.

Grossularite (including *Cinnamon Stone, Essonite, Succinite*). A lime alumina-garnet, $Ca_3Al_2O_{12}Si_3$ = Silica 40·1, alumina 22·7, lime 37·2 = 100, but often with some iron protoxide in place of part of the lime. G. = 3·4–3·75. *Grossularite* is pale green, and was hence named from the Latin for gooseberry. *Cinnamon Stone* or *Essonite* is cinnamon-colored. *Succinite* is amber-colored.

Pyrope. A magnesia alumina-garnet $Mg_3Al_2O_{12}Si_3$. Color deep red, but varying to black and green. G. = 3·15–3·8.

Spessartite. A manganese alumina-garnet $(Mn, Fe)_3Al_2O_{12}Si_3$, some iron replacing part of the manganese. Color red, brownish red, hyacinth-red. G. = mostly 4–4·4. A Haddam specimen afforded Silica 35·8. alumina 18·1, iron protoxide 14·9, manganese protoxide 31·0.

II. IRON-GARNET.

Andradite. A lime iron-garnet, $Ca_3Fe_2O_{12}Si_3$. Colors various, from that of almandite or common garnet, to a wine-yellow, as in *Topazolite;* green, as in *Jelletite;* and black, as in *Melanite* and *Pyreneite.* G. = 3·64–4.

Colophonite. A dark red to brownish yellow coarse granular garnet having often iridescent hues.

Aplome. A red variety.

Rothoffite. Has manganese in place of part of the lime, and a yellowish brown to reddish brown color.

Ytter-garnet. Contains yttria in place of part of the lime.

Bredbergite. A lime-magnesia iron-garnet.

III. CHROME-GARNET.

Ouvarovite. An emerald-green lime chrome-garnet, $Ca_3Cr_2O_{12}Si_3$, with some alumina. G. = 3·41–3·52.

Diff. The vitreous lustre of fractured garnet, and its usual dodecahedral and trapezohedral forms, are easy characters for distinguishing it.

Obs. Occurs abundantly in mica schist, hornblende schist, and gneiss, and somewhat less frequently in granite and granular limestone; sometimes in serpentine; occasionally in trap, and other igneous rocks. A massive buff-colored garnet, occurring in thin layers, in hydromica (sericite) schist, in Belgium, is the material of the finest of razor-stones.

The best *precious garnets* are from Ceylon and Greenland; *cinnamon stone* comes from Ceylon and Sweden; *grossularite* occurs in the Wilui River, Siberia, and at Tellemarken in Norway; *green garnets* are found at Schwartzenberg, Saxony; *melanite*, in the Vesuvian lavas; *ouvarovite*, at Bissersk in Russia; *topazolite*, at Mussa, Piedmont.

In the U. States, fine clear red crystals occur in Delaware Co., Pa.; Stony Point, N. C. Crystals of a *dark-red color*, of small size at Hanover, N. H.; large, some 1½ in., at Haverhill and Springfield, N. H.; large at New Fane, Vt.; at Unity, Brunswick, Streaked Mountain, Albany, etc., Me., some of the Albany garnets weighing each 20 lbs.; at Monroe, Lyme, and Redding, Ct.; Bedford, Chesterfield, Barre, Brookfield, and Brimfield, Mass.; very large and fine at Russell, Mass.; Roger's Rock, Essex Co., N. Y.; Franklin, N. J.; Avondale, Chester, Darby, and elsewhere, Pa.; Burke, Caldwell, and Catawba Cos., N. C., especially fine 8 m. S. E. of Morgantown, and near Warlick, in Burke Co.; large and fine in Alaska, near Ft. Wrangel. *Essonite* at Carlisle and Boxborough, Mass.; with idocrase at Parsonsfield, Phippsburg and Rumford, Me.; Amherst, N. H.; Amity, N. Y.; Franklin, Sussex Co., N. J.; Dixon's Quarry, seven miles from Wilmington, Del., in fine trapezohedrons. *Grossularite*, Good Hope mine, Cal.; Gila Cañon, Arizona. *Melanite*, at Franklin, N. J., and Germantown, Pa. *Ouvarovite*, at Wood's chrome-mine, Lancaster Co., Pa.; Orford and Wakefield, Canada. *Colophonite*, at Willsborough and Lewis, Essex Co., N. Y.; N. Madison, Conn. *Colorless* at Hull, Canada.

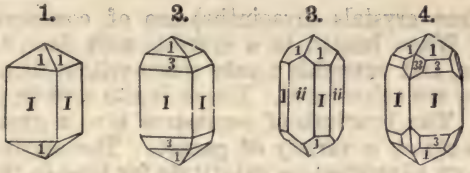
Garnet is the carbuncle of the ancients. The alabandic carbuncles of Pliny were so called because cut and polished

at Alabanda, and hence the name *Almandine* now in use. The garnet is also supposed to have been the *hyacinth* of the ancients.

Clear deep-red garnets make a rich gem, and are much used; those of Pegu are most valued. They are cut thin, on account of their depth of color. Cinnamon-stone is also employed for the same purpose. Powdered garnet is sometimes used as emery. Pliny describes vessels, of the capacity of a pint, formed from large carbuncles, "devoid of lustre and transparency, and of a dingy color," which probably were large garnets.

Zircon.

Tetragonal; $I \wedge 1 = 132° 10'$; $1 \wedge 1 = 123° 19'$. Cleavage parallel to *I*, but imperfect. Usually in crystals; but also granular.



Color brownish red, brown, and red, of clear tints; also yellow, gray, and white. Streak uncolored. Lustre more or less adamantine. Often transparent; also nearly opaque. Fracture conchoidal, brilliant. H. = 7·5. G. of purest crystals = 4·6–4·86, but varies from 4–4·9.

Composition. ZrO_2Si ($= 2ZrO + SiO_2$) = Silica 33, zirconia 67 = 100. B.B. infusible, but loses color.

Varieties. Transparent red specimens are called *hyacinths;* colorless, from Ceylon, having a smoky tinge, *jargon* (sold for inferior diamonds, which they resemble, though much less hard). Gray and brownish varieties sometimes called *zirconite.*

Diff. Readily distinguished from species which it resembles by its crystals, specific gravity, and adamantine lustre.

Obs. Confined to crystalline rocks, occurring in granite, granulyte, gneiss, granular limestone, and some igneous rocks. Zircon-syenyte is an elæolite-syenyte with disseminated zircons. Crystals often occur in auriferous sands. Hyacinth occurs mostly in grains in such sands, and comes from Ceylon; Auvergne, Bohemia, and elsewhere in Europe.

Siberia affords large zircons. Fine specimens come from Greenland. *Beccarite* is an olive-green var. from Ceylon.

In the United States, gray crystals occur in Buncombe Co., N. C.; and common in the gold sands of Polk, McDowell, Rutherford, and other cos., N. C.; cinnamon-red in Moriah, Essex Co., Two Ponds and elsewhere, Orange Co., Hammond, St. Lawrence Co., and Johnsbury, Warren Co., N. Y.; Franklin, N. J.; Litchfield, Me.; Middlebury Vt.; fine near the Pike's Peak toll-road, due west of the Cheyenne Mts.; also elsewhere in the Pike's Peak region. Canada, at Grenville, etc., also in Renfrew Co., one crystal reported nearly 10 in. long and 4 in. through, weighing 12 pounds.

Named *hyacinth* from the Greek *huakinthos;* but it is doubtful whether the ancients so called stones of the zircon species.

The clear crystals (hyacinths) are of common use in jewelry. When heated in a crucible with lime, they lose their color, and resemble a pale straw-yellow diamond, for which they are substituted. Zircon is also used in jewelling watches. The hyacinth of commerce is to a great extent cinnamon-stone, a variety of garnet. The earth zirconia is used as an advantageous substitute for lime in the oxyhydrogen lantern.

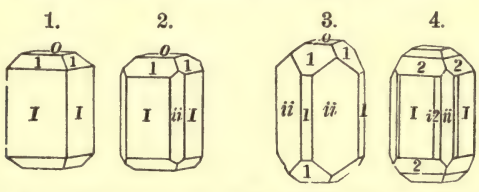
Auerbachite, Malacon, Tachyaphaltite, Œrstedite, Bragite, are names of zircon-like minerals supposed to be zircon partly altered. *Alvite* is similar in form to zircon. *Heldburgite* is probably near zircon.

Lovenite. Zirconium-calcium-sodium silicate; monoclinic; brown, yellowish. Norway.

The earth zirconia is also found in the rare minerals *eudialyte* and *wöhlerite;* also in *polymignite, æschynite;* also sparingly in *fergusonite.*

Vesuvianite.—Idocrase.

Tetragonal. $O \wedge 1 = 142° 46'$; $1 \wedge 1 = 129° 21'$, $1 : i\text{-}i$



$= 127° 14'$. Cleavage not very distinct parallel with *I.* Also massive granular, and subcolumnar.

Color brown; sometimes passing into green. Some varieties oil-green in the direction of the axis and yellowish green transverse to it. Streak uncolored. Lustre vitreous. Subtransparent to nearly opaque. H. = 6·5. G. = 3·33–3·4.

Composition. $(\frac{4}{7}Ca_3\frac{3}{7}Al)_2O_{12}Si_3$. A small part of the Ca is usually replaced by magnesium, and part of the aluminium sometimes by iron in the sesquioxide state. Percentage of a common variety, Silica 37·3, alumina 16·1, iron sesquioxide 3·7, lime 35·4, magnesia 2·1, iron protoxide 2·9, water 2·1 = 99·6. B.B. fuses easily with effervescence to a greenish or brownish globule.

Diff. Resembles some brown garnet, tourmaline and epidote, but differs in crystallization, and in greater fusibility.

Obs. First found in the lavas of Vesuvius, and hence the name. Occurs in Piedmont; near Christiania, Norway; in Siberia; in the Fassa Valley. *Cyprine* includes blue crystals from Tellemarken, Norway; supposed to be colored by copper.

In the U. States, in fine crystals at Phippsburg and Rumford, Sandford, Parsonsfield and Poland, Me.; Newton, N. J.; Amity, N. Y.; in Canada at Calumet Falls, and at Grenville.

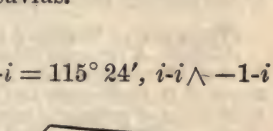
Named from the Greek *eido,* to see, and *krasis,* mixture; because its crystalline forms have much resemblance to those of some other species.

Sometimes cut as a gem for rings.

Mellilite in honey-yellow crystals (which includes *Humboldtilite*), is a related tetragonal species, from Capo di Bove, near Rome and Mount Somma, Vesuvius.

Epidote.

Monoclinic; $C = 89° 27'$; $i\text{-}i \wedge 1\text{-}i = 115° 24'$, $i\text{-}i \wedge -1\text{-}i = 116° 18'$, $-1 \wedge -1 = 109° 35'$. Cleavage parallel to $i\text{-}i$; less distinct parallel to $1\text{-}i$. Also massive granular and forming rock masses; sometimes columnar or fibrous.



Color yellowish green (pistachio-green) and ash-gray or hair-brown. Trichroic. Streak uncolored. Translucent to opaque. Lustre vitreous, a

little pearly on *i-i*; often brilliant on the faces of crystals. Brittle. H. = 6–7. G. = 3·25–3·5.

Composition. A lime-iron-aluminium silicate, the iron being mostly in the sesquioxide state and replacing aluminium, and the water basic; and the hydrogen to the calcium as 1 : 4. $R_5Al_3O_{26}Si_6$ = Silica 37·83, alumina 22·63, iron sesquioxide 15·02, iron protoxide 0·93, lime 23·27, water 2·05 = 100·73.

B.B. fuses with effervescence to a black glass which usually is magnetic. Partially decomposed by hydrochloric acid, but if first ignited, is then decomposed, and the solution gelatinizes on evaporation.

Green epidote is often called *Pistacite*. *Piedmontite* is a variety containing much manganese, of reddish brown or reddish black color. *Bucklandite* is an iron epidote.

Diff. The peculiar yellowish green color of ordinary epidote distinguishes it at once. From zoisite and vesuvianite it differs in fusing to a black magnetic globule. The ash-gray mineral related to epidote is mostly zoisite.

Obs. Occurs in crystalline rocks, especially in hornblendic rocks. Often occurs in the cavities of amygdaloidal rocks. In crystals, six inches long, and with brilliant faces and of rich color, at Haddam, Ct.; crystallized also at Franconia, N. H.; Hadlyme, Chester, Newbury, and Athol, Mass.; near Unity, Amity, and Monroe, N. Y.; Franklin, Warwick, and Roseville, N. J.; Pennsylvania, at W. Bradford and E. Bradford; Hampton, Yancey Co., N. C.; Michigan, in the Lake Superior region; Canada, at St. Joseph.

Named *epidote* by Haüy from the Greek *epididōmi*, to increase, in allusion to the fact that the base of the primary is frequently much enlarged in the crystals.

Picroepidote. Supposed to be a magnesian epidote. Siberia.

Allanite. A cerium epidote, the crystals similar; black to pinchbeck-brown; lustre submetallic to pitch-like and resinous. H. = 5·5–6; G. = 3–4·2; B.B. fuses easily and swells up to a dark, blebby magnetic glass; most varieties gelatinize with hydrochloric acid, but not after ignition. Norway; Sweden; Greenland; Scotland; Snarum, near Dresden; Topsham, Me.; Bolton quarry, Mass.; Moriah, Essex Co., Monroe, Orange Co., N. Y.; Franklin, N. J.; at East Bradford and Eaton, Pa.; Amherst Co., Va.; in Canada, at St. Paul's.

Orthite. A variety of allanite in long slender crystals: occurs in Amelia Co., Va.; N. Carolina. *Vasite* is altered orthite. *Muromontite*, *Bodenite*, and *Michaelsonite* are related minerals.

Gadolinite. Color greenish-black; monoclinic, with $I \wedge I = 116°$;

H. = 6·5–7; G. = 4–4·5; contains lithium, cerium, and beryllium, with SiO_2 25 p. c. Sweden; Greenland; Norway.

Rinkite. Monoclinic; yellowish brown. Titanium-cerium-lanthanum-calcium silicate, with fluorine. Greenland.

Mosandrite. Monoclinic. Reddish brown, dull greenish, yellowish brown; H. = 4; G. = 2·9–3·03; silicate of cerium, lanthanum, didymium, calcium, and titanium. Brevig, Norway.

Zoisite.—Lime-Epidote.

Orthorhombic; $I \wedge I = 116° 40'$. Cleavage brachydiagonal, perfect. Also columnar and massive.

Color ash-gray to white; also greenish gray, red (*Thulite*). Lustre vitreous to sub-pearly. H. = 6·6. G. = 3·11–3·38.

Composition. Like epidote, but with little or no iron. That of Ducktown, Tenn., afforded Silica 39·61, alumina 32·89, iron sesquioxide 0·91, iron protoxide 0·71, magnesia 0·14, lime 24·50, water 2·12 = 100·88. B.B. swells up and fuses to a blebby glass; gelatinizes with hydrochloric acid after ignition. Unlike hornblende in its one perfect cleavage.

Obs. From Saualpe, Carinthia, in the Tyrol; Arendal, etc.; Willsboro' and Montpelier, Vt.; Goshen, Chesterfield, etc., Mass.; Unionville and Leiperville, Pa.; Ducktown copper-mine, Tenn.

Saussurite. Fine-grained and tough; white, bluish or yellowish white, grayish; G. = 3–3·5. Results from the alteration of a triclinic feldspar, the form or cleavage of which is sometimes retained. The chief constituent of the euphotide (p.) of the Alps, Mt. Genevre, Orezza, Corsica. Hunt made the saussurite of the Alps (G. = 3·36–3·385), by his analyses, a soda-bearing zoisite (silica 43·6 and 48·1). Most kinds are between zoisite and anorthite or labradorite in composition, and are apparently altered forms of these feldspars. Has been made a *mixture* of zoisite and a feldspar. A kind from Wildschönau, having G. = 3·011, and silica 48·3 p. c., is made by Cathrein such a mixture, but more investigation is needed. Altered anorthite crystals from Hanover, N. H., of similar characters, with G. = 2·96, have nearly, according to Hawes, the composition of labradorite (silica 52·52 p. c.). The high specific gravity separates the mineral from the feldspars.

Arctolite. Near zoisite; G. = 3·03. From crystalline limestone. Spitzbergen. *Balvraidite*, from limestone in Scotland, is of similar composition.

Ilvaite (*Yenite*). In orthorhombic striated prisms; $I \wedge I = 112° 38'$; iron-black to grayish black; H. = 5·5–6; G. = 3·7–4·2; in composition a calcium-iron silicate in which part of the iron is in the sesquioxide state. Elba; Fossum and Skeen, Norway, etc. Reported as occurring at Cumberland, R. I.; Milk Row quarry, in Somerville, Mass.; near Manayunk, Pa. Named *Ilvaite* from the Latin name of Elba.

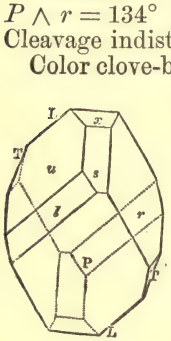
Ardennite. Near Ilvaite in crystals and low p. c. of silica, but contains much manganese oxide and more or less of vanadium pentoxide; G. = 3·620; clear yellow to brown. Ardennes, Belgium.

Barylite. A silicate containing 46·23 of baryta; H. = 7; G. = 4·03; colorless; the oxygen ratio for bases and silica 10 : 7, or that of a sub-silicate. Longban, Sweden.

Axinite.

Triclinic. In acute-edged oblique rhomboidal prisms; $P \wedge r = 134° 45'$, $r \wedge u = 115° 38'$, $P \wedge u = 135° 31'$. Cleavage indistinct. Also rarely massive or lamellar.

Color clove-brown; differing somewhat in shade in three directions, being trichroic. Lustre vitreous. Transparent to subtranslucent. Brittle. H. = 6·5–7. G. = 3·27. Pyroelectric.



Composition. A unisilicate, containing boron. One analysis afforded Silica 43·68, boron trioxide 5·61, alumina 15·63, iron sesquioxide 5·45, manganese sesquioxide 3·05, lime 20·92, magnesia 1·70, potash 0·64 = 100·43. B.B. fuses easily with intumescence to a dark green or black glass, imparting a pale green color to the flame which is due to the boron.

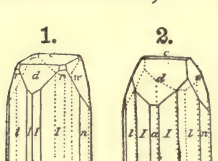
Diff. Remarkable for the sharp thin edges of its crystals, their glassy brilliant appearance, and absence of cleavage; implanted, and not disseminated like garnet. In one or all of these particulars, and also in blowpipe reaction, it differs from any of the titanium ores.

Obs. Occurs at St. Christophe in Dauphiny; Kongsberg in Norway; Normark in Sweden; Santa Maria, in Switzerland; Cornwall, England; Thum in Saxony, whence the name *Thummerstein* and *Thummite.*

In the U. States, at Phippsburg and Wales, Me.; Cold Spring, N. Y.; Bethlehem, Pa.

Danburite.

Orthorhombic; $I : I = 122° 52'$; resembles topaz in its crystals. Also massive. Color pale-yellow, honey-yellow. Transparent. Lustre vitreous, slightly greasy when massive. H. = 7–7·25. G. = 2·986–3·021.



Composition. A calcium-silicate containing much boron; $(\frac{1}{3}Ca_3 \frac{2}{3}B)_2, O_{12}Si_8$. In an analysis, SiO_2 48·23, B_2O_3 26·93, Al_2O_3 0·47, Fe_2O_3 *tr.*, CaO 23·24, ign.

0·63 = 99·50. B.B. fuses to a colorless glass; reaction for boron, which distinguishes it easily.

Obs. From Danbury, Ct.; Russell, N. Y., in large crystals; Switzerland.

Iolite.—Dichroite. Cordierite.

Orthorhombic; $I \wedge I$ near 120°. Commonly in 6- and 12-sided prisms. Also massive. Cleavage indistinct; but crystals often separable into layers parallel to the base, especially after partial alteration.

Color various shades of blue, looking often like a pale or dark blue glass; often deep blue in direction of the axis, and yellowish gray transversely. Streak uncolored. Lustre vitreous. Transparent to translucent. Brittle. H. = 7–7·5. G. = 2·6–2·7.

Composition. A silicate of aluminium, magnesium, and iron, corresponding to Silica 49·4, alumina 33·9, magnesia 8·8, iron protoxide 7·9 = 100. B.B. loses its transparency; fuses with much difficulty.

Diff. Resembles blue quartz, and is distinguished by fusing on the edges. Easily scratched by sapphire.

Obs. Found at Haddam, Ct., in granite; also in gneiss at Brimfield, Mass.; at Richmond, N. H.; at Bodenmais in Bavaria; Arendal, Norway; Capo de Gata, Spain; Tunaberg, Finland; Norway; Greenland; Ceylon.

Named from the Greek *ion*, violet, alluding to its color; and *dichroite*, from *dis*, twice, and *chroa*, color, referring to the different colors in two directions.

Occasionally employed as an ornamental stone, and is cut so as to present the different shades of color in different directions.

Iolite exposed to the air and moisture undergoes a gradual alteration, becoming hydrous, and assuming a foliated micaceous structure so as to resemble talc, though more brittle and hardly greasy in feel. *Hydrous Iolite, Fahlunite, Chlorophyllite,* and *Esmarkite* are names that have been given to the altered iolite; and *Gigantolite* and a number of other like minerals are of the same origin. (See p. 315.)

MICA GROUP.

The minerals of the mica group are alike in having (1) their crystals monoclinic; (2) the front plane angle of the base, or of the cleavage laminæ, 120°; (3) cleavage eminent, parallel to the base, affording very thin laminæ; and (4) *aluminium* and *potassium* among the essential constituents;

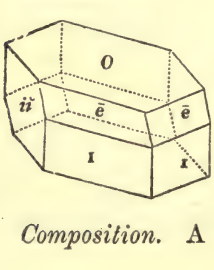
sodium is often present, but only one species, *paragonite*, contains sodium instead of potassium. In *muscovite* and *paragonite* the protoxide elements are almost solely the alkali metals, with hydrogen (of the water present); in *phlogopite*, they are potassium and magnesium; in *biotite* and some related kinds, potassium, magnesium, and iron; in *annite*, potassium and iron; in *cryophyllite*, much potassium and much lithium with some iron. *Zinnwaldite* is near the last. One, *Œllacherite*, contains near 6 p. c. of barium with the potassium. Fluorine is present in most mica.

The combining or oxygen ratio for the bases (the water being included) is mostly 1 to 1; but in some kinds the silicon is in excess, and the ratio becomes, at the extreme, 1 to $1\frac{1}{2}$, as in zinnwaldite and some muscovite.

The ordinary light-colored micas are mostly muscovite, and the black, mostly biotite. The optic-axial plane in most micas passes through the longer diagonal of the base, being perpendicular to the plane of symmetry. In a blackish Vesuvian mica (meroxene) and in phlogopite and zinnwaldite, it passes through the shorter diagonal of the base. Lepidolite is a light-colored mica containing lithia, belonging with muscovite. Muscovite and biotite are so related that crystals of the latter often occur that are finished out uninterruptedly by muscovite, the axial lines of the one continuous with those of the other; and such crystals are sometimes several inches across; there is here a compound structure chemically, but no twinning in the crystallization. When a thin plate of mica is struck with a pointed awl or other like tool a symmetrical star of six rays is produced, the rays being cleavage lines parallel to the sides of the rhombic prism *I* and the shorter diagonal.

Muscovite.—Common Mica.

Monoclinic. Usually in plates or scales. Sometimes in radiated groups of aggregated scales (plumose mica); rarely spheroidal.



Colors from white through green, yellowish and brownish shades; rarely rose-red or reddish violet. Lustre more or less pearly. Transparent or translucent. Tough and elastic. H. = 2–2·5. G. = 2·7–3. Optic-axial angle 44° to 78°.

Composition. A common variety has the general formula

$(\frac{1}{4}R_3\frac{3}{4}R)_2O_{12}Si_3$, R including K_2 and H_2, and R, aluminium and some iron in the sesquioxide state. An analysis of mica of this variety obtained Silica 46·3, alumina 36·8, iron sesquioxide 4·5, potash 9·2, fluorine 0·7, water 1·8 = 99·3; 3 to 5 p. c. of water often present, and passes thus to a hydrous mica. The variety *Phengite* contains more silica. B.B. whitens and fuses on the thinnest edges with difficulty to a gray or yellow glass. Some altered mica exfoliates B.B.

Diff. Differs from talc and chlorite in being elastic, the folia tougher and harder; yet hydrous varieties sometimes have a greasy feel, and little or no elasticity.

Obs. A constituent of granite, gneiss, and mica schist, but not as commonly so as biotite. The larger crystallizations occur in granite veins, intersecting these rocks. Along a belt of country in New England east of the Connecticut, in New Hampshire, Massachusetts, and Connecticut, and to the southwest, in Maryland, Virginia, North Carolina, South Carolina, Alabama, and Georgia, large granite veins occur, and many valuable deposits of mica have been opened. The chief mines of New England are at Alstead, Grafton, and Groton, where plates two to three feet across have been obtained; mines occur in Virginia, but more important in North Carolina, in Yancey, Mitchell, and Macon, and other cos.; Dakota affords much mica, chiefly from Custer and Pennington cos. in the Black Hills. Mines have been opened also in Colorado, New Mexico, etc.; in Canada (Ontario) in N. Burgess, Villeneuve, etc. Mica occurs also in interesting forms at Paris, Me.; Chesterfield, Barre, Brimfield, and South Royalston, Mass.; near Middletown and Branchville, Ct.; near Greenwood Furnace, Warwick, and Edenville, Orange Co., and in Jefferson and St. Lawrence cos., N. Y.; Newton and Franklin, N. J.; near Germantown, Pa.; Jones's Falls, Md.

Mica was formerly used in Siberia for glass in windows, whence it has been called *Muscovy glass.* It is in common use in lanterns; for the doors of stoves and furnaces and for other purposes which demand a tough transparent substance not easily affected by heat. It is also ground for some ornamental purposes. About 150,000 pounds of sheet mica ($370,000) was the product in the United States for 1884, and 92,000 pounds ($161,000), for 1885.

Lepidolite. A lithium-bearing muscovite; color rose-red, and lilac to white; in crystalline plates and aggregations of scales. It contains

from 2 to 5 per cent of lithia, and hence B.B. imparts a deep crimson color to the flame. It is mostly of the species muscovite, and the rest is zinnwaldite. The formula, $LiKAl_2O_9F_2Si_3$ = Silica 49·18, alumina 27·87, lithia 4·09, potash 12·81, fluorine 9·84 = 103·79. Rozena, Moravia; Saxony; the Ural; Sweden; Cornwall; Paris, Hebron, etc., Maine; Chesterfield, Mass.; Middletown, Ct. The red mica of Goshen is not lithium-bearing.

Margarodite, Hygrophilite, Damourite, Sericite, Sterlingite. Names for micas related to muscovite, but containing 4 or 5 per cent. of water. While mica becomes hydrated on weathering, much mica was hydrous at its origin. A hydrous mica is distinguished by its greasy feel and little elasticity. The compact pseudomorphous material called *Pinite* has the constitution of a hydrous mica.

Œllacherite. Like whitish muscovite in its elastic laminæ, polarization, and other characters; but an analysis obtained only 7·6 p. c. of potash (with 1·4 of soda), along with about 5 p. c. of baryta, and 4·4 of water. Kemmat, in Pfitschthal.

Paragonite. Resembles much muscovite; occurs in pearly scales constituting a schistose rock; G. = 2·75–2·9; formula like that given under muscovite; an analysis afforded Silica 46·81, alumina 40·06, magnesia 0·65, lime 1·26, *soda* 6·40, water 4·82 = 100. Monte Campione, in the region of St. Gothard. *Pregrattite* and *Cossaite* are the same.

Cryophyllite. Like a green muscovite and similar in optic-axial angle. G. = 2·909. But an analysis obtained, besides 13·15 p. c. of potash, 4 of lithia and 8 of iron protoxide, with 2·49 of fluorine; another 10·6 of K_2O, 0·8 of Na_2O, 4·9 of Li_2O, and about 7.1 of fluorine. Owing apparently to the unusual percentage of alkali and fluorine, it is remarkable for its fusibility, it fusing in the flame of a candle; to this the name, from the Greek *kruos*, ice, alludes. The granite of Cape Ann, Mass.

Zinnwaldite is similar to the last in containing iron and lithium without magnesium, but the amount of alkali metal is proportionally less, and fusion is less easy. Zinnwald.

Polylithionite is very similar, but contains 59 p. c. SiO_2. Greenland.

Phlogopite.

Monoclinic. Color often yellowish brown with a copper-like reflection; also brownish yellow to white. Optic-axial angle 3° to 20°.

Composition. Mostly $(\frac{2}{3}R_3\frac{1}{3}Al)_4O_{26}Si_4$, in which (HK): Mg = 1 to 5. An analysis afforded Silica 43·00, alumina 12·37, iron sesquioxide 1·71, magnesia 27·70, potash 10·32, soda 0·30, water 0·38, fluorine 5·67 = 102·35. B.B. like muscovite, but reaction for more fluorine.

Obs. From the crystalline limestone of St. Lawrence, Jefferson, Essex, and Orange cos., N. Y., and Sussex Co., N. J.; Burgess, Canada, etc.

Aspidolite is a related mica.

Biotite.

Monoclinic. Crystals usually short, erect, rhombic or hexagonal prisms. Twins of six individuals not infrequent, as optically detected. Common in disseminated scales; also in masses made up of an aggregation of scales.

Color dark green to black, rarely white. Transparent to opaque. Lustre more or less pearly on a cleavage surface. Optic-axial angle often less than 1°; crystals often apparently uniaxial. H. = 2·5–3. G. = 2·7–3·1.

Composition. Mostly $(\frac{1}{3}R_3\frac{2}{3}R)_2O_{12}Si_3$, in which R = iron, magnesium, potassium, and hydrogen (of water present), and R = aluminium. In one analysis, Silica 40·00, alumina 17·28, iron sesquioxide, 0·72, iron protoxide 4·88, magnesia 23·91, potash 8·57, soda 1·47, water 1·37, fluorine 1·57 = 99·77. B.B. whitens and fuses on thin edges; sometimes a red flame from reaction for lithium. This species has been called *Anomite*. *Euchlorite* is biotite. The approach to uniaxial character optically in this mica has been explained by J. P. Cooke on the view of a twinning between successive laminæ, making an overlapping compound structure.

Obs. Common as a constituent of mica schist, gneiss, and granite, much more common than muscovite; often present in syenyte; occurs in black scales in some trachytes. While differing from muscovite in the presence of magnesium and iron, the percentage of potash is but little less (about 9 per cent.). Occurs in large black, greenish, and brownish-black crystallizations at Greenwood Furnace, Monroe, N. Y.; in veins in granite at Middletown, Portland, and Stony Creek, Ct., a kind affording lithia reactions, and oxidizing easily; Moriah, Essex Co., N. Y.; Topsham, Me., crimson; Easton, Pa., white.

Meroxene. The so-called biotite, or black mica, of Vesuvius; unlike biotite, it has the optic-axial plane parallel (instead of at right-angles to) the plane of symmetry.

Lepidomelane. Resembles biotite, but thin folia are but little elastic, or are brittle, and the proportion of iron oxide is larger (20 to 30 p. c.), with less magnesia (3 to 7 p. c.). Wermland, Sweden.

Haughtonite. Between biotite and lepidomelane. Contains 7 to 15 p. c. of magnesia. Fuses with difficulty. From granite, dioryte, etc., of Ireland.

Annite. Related to lepidomelane, but contains almost no magnesia (0·60 p. c.). From Cape Ann. Another, of same loc., contains less silica (32 p. c.) and much more FeO (30·3). Annite crystals have sometimes a border of cryophyllite.

Siderophyllite. Like Annite in the near absence of magnesia (1·14 p. c.); B.B. fuses easily. From Pike's Peak.

Astrophyllite. A mica of doubtful relations; has been referred to the pyroxene group; has the small amount of silica (32–35 p. c.) that characterizes the chlorite group, and 3·5–4·5 p. c. of water; contains besides iron protoxide, 7 to 14 p. c. of titanium dioxide and some zirconia and potash. Norway; El Paso Co., Col.

SCAPOLITE GROUP.

The Scapolite species are tetragonal in crystallization, usually white in color or of some light shade, and analyses afford alumina and lime with or without soda. The lime scapolites are unisilicate in ratio; the others, containing alkali, have, with one exception, more silica than this ratio requires.

Wernerite.—Scapolite.

Tetragonal; $1 \wedge 1 = 136° 7'$. Cleavage rather indistinct parallel with *i-i* and *I*. Also massive, sublamellar, or sometimes faintly fibrous in appearance.

Colors light; white, gray, pale blue, greenish or reddish; brown when impure. Streak uncolored. Transparent to nearly opaque. Lustre usually a little pearly. H. = 5–6. G. = 2·65–2·8.

Composition. $(\frac{3}{4}[Ca,Na_2]\frac{8}{3}Al)_2O_{12}Si_9$ = Silica 48·4, alumina 28·5, lime 18·1, soda 5·0 = 100; but contains also 1 to 2·5 p. c. of chlorine. B.B. fuses easily with intumescence to a white glass; imperfectly decomposed by hydrochloric acid.

Diff. The square prisms and the angle of the pyramid at summit are characteristic. In cleavable masses it resembles a feldspar, except for a slight fibrous appearance usually distinguished on the cleavage surface. More fusible than feldspar, and of higher specific gravity. Spodumene has a much higher specific gravity, and differs also B.B. Wollastonite is more fibrous in the appearance of the surface, is less hard, and gelatinizes with acids.

Obs. Found mostly in the older crystalline rocks, and also in some volcanic rocks; especially common in granular limestone. Crystals occur at Gouverneur, Two Ponds, Amity, N. Y.; Bolton, Boxborough, Littleton, Mass.;

Franklin, Newton, N. J.; massive at Marlboro', Vt.; Westfield, Mass.; Monroe, Tyringham, Ct. Foreign localities are at Arendal, Norway; Wermland, Sweden; Pargas in Finland.

Chelmsfordite, Nuttallite, Ontariolite, Glaucolite, are varieties of this species. *Paranthine* and *Ekebergite* are similar, being distinguishable from it only by chemical analysis.

Sarcolite. Tetragonal and like wernerite; reddish white to rose-red; H. = 6; G. = 2·9–2·95; formula $(\frac{1}{2}Ca_3\frac{1}{2}Al)_2O_{12}Si_3$; gelatinizes with acids. In small geodes, Mt. Somma.

Meionite. A lime scapolite, like wernerite in crystals, but having the formula $(\frac{1}{2}Ca\frac{3}{2}Al)_2O_{12}Si_3$, being a true unisilicate. Monte Somma.

Dipyre is near wernerite, but contains more silica (56 p. c.) and 10 per cent. of soda. The Pyrenees.

Mizzonite and *Marialite* are other kinds containing much soda and silica, the latter 60 p. c.

Nephelite.—Nepheline.

Hexagonal. In hexagonal prisms with replaced basal edges; $O \wedge 1 = 135° 55'$. Also massive; rarely thin columnar.

Color white, or gray, yellowish, greenish, bluish red. Lustre vitreous to greasy. Transparent to opaque. H. = 5·5–6. G. = 2·55–2·62.

Composition. $(Na_2, K_2)_4Al_4O_{34}Si_9$, the oxygen ratio being $1 : 3 : 4\frac{1}{2}$. An analysis afforded Silica 44·0, alumina 33·3, Fe_2O_3, MnO_2 0·7, lime 1·8, soda 15·4, potash 4·9, water 0·2 = 100·3; a little lime is usually present. B.B. fuses quietly to a colorless glass. Decomposed by hydrochloric acid, and the solution gelatinizes easily on evaporation.

Named from the Greek *nephelē*, cloud, the mineral becoming clouded in acid. Includes the glassy crystals from Vesuvius called *Sommite;* also hexagonal crystals in other volcanic rocks; a massive variety, of greasy lustre, called *Elæolite* from the Greek *elaion,* oil. Altered crystals are in part the mineral *Gieseckite.*

Diff. Distinguished from most scapolites and feldspars by the greasy lustre when massive, and the facility with which it gelatinizes with acids; from apatite by the last character, and also its greater hardness.

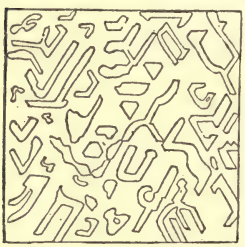
Obs. The prominent constituent of nephelindoleryte or nephelinyte, and phonolyte, and also in some other eruptive rocks; enters into the constitution of miascyte, zirconsyenyte, and some metamorphic rocks. Among the localities are Vesuvius and C. di Bove, in Italy; Katzenbuckel, near

Heidelberg; Aussig, in Bohemia; and as elæolite, Brevig, Norway; Siberia; the Ozark Mountains, Arkansas; Litchfield, Maine.

Cancrinite. Like nephelite in crystallization, also in composition, except the presence of some carbonates and usually water; color white, gray, yellow, green, blue, or reddish; H. = 5-6; G. = 2·4–2·5; on account of the carbonates it effervesces in acids. B.B. fuses very easily.

Occurs in crystalline rocks at Miask in the Ural; in Norway; Transylvania; and at Litchfield in Maine, with elæolite and sodalite.

Microsommite. Near nephelite in form; also in composition, except the presence of much chlorine (6·2 to 8 p. c.) and sulphuric acid (4 to 5·26 p. c.); colorless to yellow. In large crystals from Mt. Somma; and in small from bombs ejected by Vesuvius in 1872. *Davyne* is in part altered microsommite.



Eucryptite. Hexagonal. Crystallized microscopically within albite, in forms like those of the quartz of graphic granite, as in the figure. Composition $Li_2Al_2O_6Si_2$, near that of nephelite. Both the albite and eucryptite a result of the alteration of spodumene, at Branchville, Ct.; and shown by Brush and E. S. Dana to be an intermediate stage in the change from spodumene to muscovite. Gelatinizes in acid.

Sodalite.

Isometric. In dodecahedrons; cleavage dodecahedral. Color brown, gray, or blue. Lustre vitreous, sometimes greasy. H. = 6. G. = 2·25–2·4.

Composition. $Na_2AlO_3Si_2 + \frac{1}{2}NaCl$ = Silica 37·1, alumina 31·7, soda 19·2, sodium 4·7, chlorine 7·3 = 100. B.B. fuses with intumescence to a colorless glass. Decomposed by hydrochloric acid, and the solution gelatinizes on evaporation.

Occurs in eruptive and metamorphic rocks. Found in Sicily; near Lake Laach; at Miask; in Norway; W. Greenland; Bolivia; blue, at Litchfield, Me.; lavender-blue at Salem, Mass.

Haüynite (or Hauyne). Near sodalite in form and composition; blue to greenish; contains about 12 p. c. of sulphuric acid. From lavas of Mt. Somma; L. Laach; Mt. Dor, etc. *Nosite* (or noscan) is similar. *Ittnerite* and *Skolopsite* are altered haüynite or nosite.

Lapis-Lazuli.—Ultramarine.

Isometric; rarely in crystals (dodecahedrons); cleavage imperfect. Usually massive. Color rich Berlin or azure blue. Lustre vitreous. Translucent to opaque. H. = 5·5. G. = 2·3–2·5.

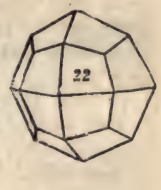
Composition. Silica 45·5, alumina 31·8, soda 9·1, lime 3·5, iron 0·8, sulphuric acid 5·9, sulphur 0·9, chlorine 0·4, water 0·1 = 98·0. B.B. fuses to a white translucent or opaque glass, and if calcined and reduced to powder, loses its color in acids. Color supposed to be due to sodium sulphide. The mineral is not homogeneous, but the exact nature of the ultramarine species at the basis of it is not yet ascertained.

Obs. Found in syenyte and granular limestone. Brought from Persia, China, Siberia, and Bucharia. The specimens often contain scales of mica and disseminated pyrites.

The richly-colored lapis-lazuli is highly esteemed for costly vases, and for inlaid work, and is used also in the manufacture of mosaics. It is the material of the beautiful and durable blue paint called *Ultramarine*, which has been a costly color. An artificial ultramarine is made which is equal to the native, and comparatively cheap; it consists of silica 45·6, alumina 23·3, soda 21·5, potash 1·7, lime *trace*, sulphuric acid 3·8, sulphur 1·7, iron 1·1, and chlorine a small quantity undetermined.

Leucite.—Amphigene.

Isometric. Form the trapezohedron, as in the figure. Cleavage imperfect. Usually in dull glassy white to gray crystals, disseminated through lava. Translucent to opaque. H. = 5·5–6. G. = 2·45–2·5. Brittle.



Composition. $K_2AlO_{12}Si_4$ = Silica 55·0, alumina 23·5, potash 21·5 = 100. B.B. infusible. Moistened with cobalt nitrate and ignited assumes a blue color. Decomposed by hydrochloric acid, without gelatinizing.

Diff. Distinguished from analcite by its hardness and infusibility.

Obs. In volcanic rocks, and abundant in those of Italy, especially at Vesuvius, where some crystals are an inch in diameter. Also found in the Leucite Hills, northwest of

Point of Rocks, Wyoming Territory; in Cerro de los Virgines, Cal.

Named from the Greek *leukos*, white. The crystals give usually the angles of a *tetragonal* form, but this is believed to be an irregularity due to the internal condition of the crystal (p. 79).

FELDSPAR GROUP.

The species of the Feldspar Group are related—

A. In crystallization: (1) the forms being all oblique; (2) the angle of the fundamental rhombic prism *I*, in each, nearly 120°; (3) the other angles differing but little, although part of the species are monoclinic and part triclinic; and (4) there being two directions of easy cleavage, one, the most perfect, parallel to the basal plane *O*, and the other parallel to the shorter diagonal section, with the intervening angle, "the cleavage angle," either 90° (as in the monoclinic species orthoclase and hyalophane), or nearly 90° (as in the triclinic species). The triclinic feldspars are often called by the general name *Plagioclase*.

B. In composition: (1) the only element in the sesquioxide state being aluminium, and those in the protoxide state potassium, sodium, or calcium, or two or three of these bases together, rarely with barium; (2) the constant ratio of 1 atom of R to 1 of R; (3) the amount of silica in the species increasing with the proportion of alkali, being that of a unisilicate in the pure lime-feldspar, anorthite; that of a tersilicate in the soda-feldspar, albite, or potash-feldspar, orthoclase; and so directly proportioned to the alkali, that the amount in any lime-and-soda feldspar may be deduced by taking the lime (or calcium) as existing in the state of a unisilicate, and the soda in that of a tersilicate, and adding the two together.

Anorthite has the formula $CaAlO_8Si_2$.
Albite " " $Na_2AlO_{16}Si_6$.

The constitution of a species containing Ca and Na_2 in the ratio of 1 to 1 for the protoxide portion may be obtained as follows. Adding together the anorthite and albite formulas, we have $CaNa_2Al_2O_{24}Si_8$; then dividing by 2, the formulas become $\frac{1}{2}Ca\frac{1}{2}Na_2AlO_{12}Si_4$, which expresses the composition of andesite. With 3 parts of the Ca unisilicate, and 1 of the Na_2 tersilicate, the composition is that

of labradorite. So it is for other combinations, that is for other species between anorthite and albite in composition; and since still other intermediate kinds exist, it is supposed that all the varieties between the two above-mentioned species are isomorphous combinations of them.

The quantivalent or oxygen ratio for the R, Al, Si, in the several species of the group, is as follows: V means *triclinic* in crystallization, and IV *monoclinic;* and K, Na, Ca, Ba, the protoxide basic element of the species.

	RATIO.	SYSTEM OF CRYSTALLIZATION.		RATIO.	SYSTEM OF CRYSTALLIZATION.
Anorthite, Ca,	1 : 3 : 4	V,	Oligoclase, Na, Ca,	1 : 3 : 9	V.
Labradorite, Ca, Na,	1 : 3 : 6	V,	Albite, Na,	1 : 3 : 12	V.
Hyalophane, Ba,	1 : 3 : 8	IV,	Microcline, K,	1 : 3 : 12	V.
Andesite, Na, Ca,	1 : 3 : 8	V,	Orthoclase, K,	1 : 3 : 12	IV.

These are the *normal* ratios; but there is variation from them in the analyses, part of which is variation in actual composition, and part a result of interlamination or mixture of two feldspars. Thus, orthoclase occurs mixed with microcline, albite, or oligoclase. But while such mixtures account for the soda found in some analyses of orthoclase, it does not for that in all, since soda does occur in many specimens of pure orthoclase, replacing part of the potash. It is the same with the triclinic feldspar microcline, which has the composition of orthoclase, and may have the alkali portion all potash or part soda, one analysis of typical microcline giving only 0·48 of soda. It is, hence, not safe to calculate the percentage of orthoclase present in a feldspar, or in a mixture, from the percentage of potash. Moreover, potash is present in much albite.

The above ratios show that anorthite has for the oxygen ratio between R + R and Si, 4 : 4, or 1 : 1, as in true unisilicates; while in albite and orthoclase, the same ratio is 4 : 12 or 1 : 3, that of a tersilicate, as above stated.

C. In physical characters: hardness between 6 and 7; specific gravity, between 2·44 and 2·75; lustre vitreous, but often pearly on the face of perfect cleavage; and each species transparent to subtranslucent.

Distinctive characters. The form is sufficient to determine a feldspar when it is in defined crystals; so also the fact of two unequal cleavages inclined to one another at 84° to 90°, one of them quite perfect. No fibrous, columnar, or micaceous varieties are known. They differ from

rhodonite, by the absence of a manganese reaction; from spodumene, by the absence of a lithia reaction as well as cleavage angle; from scapolite, by form; from nephelite, by form, and also more difficult fusibility, and by not gelatinizing with acids, except in the case of anorthite, which gelatinizes readily. For optical characters see page 78, and beyond, under Petrology.

Anorthite.—Indianite. Lime Feldspar.

Triclinic; cleavage angle 85° 50′ and 94° 10′. Crystals tabular. Also massive granular or coarse lamellar. Color white, grayish, reddish. G. = 2·66–2·78.

Composition. $CaAlO_8Si_2$ = Silica 43·1, alumina 36·8, lime 20·1 = 100. B.B. fuses with much difficulty to a colorless glass; decomposed by hydrochloric acid, and the solution gelatinizes on evaporation.

Obs. Occurs in basic eruptive rocks; also in some metamorphic rocks. Found in the lava of Vesuvius; the Tyrol; Faroe Islands, Iceland; in imbedded crystals in some doleryte of the Connecticut Valley; in altered crystals (saussurite) at Hanover, N. H.; in diabase and gabbro of Keweenaw Point; as a rock with large crystals on the north or Minnesota shore of L. Superior. *Barsowite* is referred here.

Bytownite. Near anorthite, but having more silica (46–48 p. c.), with some soda, and the oxygen ratio 1 : 3 : 5. The Minnesota anorthite gives the unusual ratio 1 : 2·4 : 4·15.

Labradorite.—Lime-soda Feldspar. Labrador Feldspar.

Triclinic; cleavage angle 93° 20′ and 86° 40′. Usually in cleavable massive forms.

Color dark gray, brown, or greenish brown; also white or colorless. Often a series of bright chatoyant colors from internal reflections, especially blue and green, with more or less of yellow, red, and pearl-gray. G. = 2·67–2·70.

Composition. $\frac{3}{4}Ca\frac{1}{4}Na_2AlO_{10}Si_3$ = Silica 52·9, alumina 30·3, lime 12·3, soda 4·5 = 100. Sometimes a little potash in place of the soda. B.B. fuses easily to a colorless glass. Only partially decomposed by hydrochloric acid.

Obs. A constituent of the larger part of basic eruptive rocks and lavas; and also of some metamorphic rocks. An ingredient in part of the Archæan rocks. Named from its first discovery in Labrador.

Andesite. Triclinic; cleavage angle 87°–88°. Near labradorite in composition; the formula $\frac{1}{3}Ca\frac{1}{2}Na_2AlO_{12}Si_4$ = Silica 59·8, alumina 25·5, lime 7·0, soda 7·7 = 100·0.

Hyalophane. Monoclinic, and, hence, the cleavage angle 90°. A baryta feldspar; the formula like that of andesite, excepting the substitution of Ba for Ca and K_2 for Na_2. G. = 2·8–2·9. Binnenthal, Switzerland; Jakobsberg, Sweden.

A *triclinic* baryta-feldspar, having the ratio of andesite, 1 : 3 : 8, and the cleavage angle 86° 37′ with G. = 2·835, has been described; it approaches oligoclase in optical characters.

Oligoclase.—Soda-lime Feldspar.

Triclinic; cleavage angle 93° 50′ and 86° 10′. Commonly in cleavable masses. Also massive.

Color usually white, grayish white, grayish green, greenish, reddish. Transparent, subtranslucent. H. = 6–7. G. = 2·5–2·7.

Composition. $\frac{1}{4}Ca\frac{3}{4}Na_2AlO_{14}Si_8$ = Silica 61·9, alumina 24·1, lime 5·2, soda 8·8 = 100. A portion of the soda is usually replaced by potash. B.B. fuses without difficulty; not decomposed by acids.

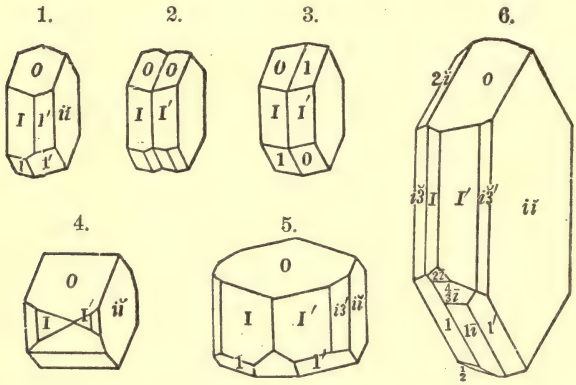
Obs. Occurs in granite, gneiss, syenyte, and various metamorphic rocks, especially those containing much silica; and in such case usually associated with orthoclase. *Sunstone* is in part oligoclase, giving bright reflection from the interior, owing to disseminated scales of hematite. Occurs in Norway. *Moonstone* is in part a whitish opalescent variety. Oligoclase occurs at Unionville, Blue Hill, Pa.; Haddam, Conn.; Mineral Hill, Del.; Chester, Mass., etc.; the Urals; Finland; Norway; Bohemia; Elba.

Albite.—Soda Feldspar.

Triclinic. Cleavage angle 93° 36′, and 86° 24′. Figures 1 to 6 represent some of its forms; 2 and 3 are twin crystals. Crystals usually more or less thick tabular. Also massive, with a granular or lamellar structure. Color white; occasionally light tints of bluish white, grayish, reddish, and greenish. Transparent to subtranslucent. H. = 6–7. G. = 2·61–2·62.

Composition. $Na_2AlO_{16}Si_6$ = Silica 68·6, alumina 19·6, soda 11·8 = 100·0. B.B. fuses to a colorless or white glass, imparting an intense yellow to the flame. Not acted upon by acids.

Cleavelandite is a lamellar variety occurring in wedge-shaped masses at the Chesterfield albite vein, Mass.



Obs. Albite occurs in some granites and gneiss, and is most abundant in granite veins. Fine crystals occur at Middletown, Haddam, and Branchville, Ct.; Goshen, Mass.; Granville, N. Y.; Unionville, Delaware County, Pa.

Named from the Latin *albus*, white.

Microcline.—Potash Feldspar.

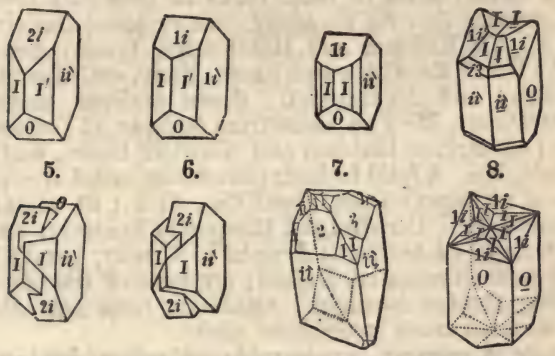
Triclinic; cleavage angle within 16′ of 90°. In angles, and also in physical characters, nearly identical with orthoclase, but the cleavage surface shows sometimes the fine striations due to twinning. When viewed with polarized light, the twinned structure is distinct, but differs from other triclinic feldspars in a blocked arrangement, owing to a transverse twinning (Fig. 13, p. 79). Colors white, flesh-red, copper-green. The green variety has been called *Amazon-stone;* the color comes, according to König, from the presence of an organic salt of iron.

Occurs in the zircon-syenyte of Norway; also in the Urals; Greenland; Labrador; Leverett, Mass.; Branchville, Ct.; Delaware; Chester Co., Pa. (*Chesterlite*); White Mountain Notch; Pike's Peak (Amazon-stone); Magnet Cove, Ark.

Orthoclase.—Common Feldspar. Potash Feldspar.

Monoclinic; the cleavage angle 90°. Figures 1 to 3 represent common forms, and 4 to 8, twins; 4, twinned

parallel to *O*; 5, 6, parallel to *i-ī*, *Carlsbad* twins; 7, parallel to 2-*ī*, *Baveno* twin; 8, same as 7, but made up of four crystals instead of two. Usually in thick prisms, often



rectangular, and also in modified tables. Also massive, with a granular structure, or coarse lamellar; also fine-grained, massive, crypto-crystalline. Colors light; white, gray, and flesh-red common; also greenish and bluish white and green. H. = 6. G. = 2·55–2·58.

Composition. $K_2AlO_{16}Si_6$ = Silica 64·7, alumina 18·4, potash 16·9 = 100. Soda sometimes replaces a portion of the potash. B.B. fuses with difficulty; not acted on by acids.

Common feldspar is the common subtranslucent variety; *Adularia*, the white or colorless subtransparent, the name derived from Adula, one of the highest peaks of St. Gothard; *Sanidin* or *glassy feldspar*, transparent tabular crystals, often occurring in trachytes and lavas; but some of the "glassy feldspar" belongs to the species oligoclase or anorthite; *Loxoclase*, a grayish variety, with a pearly or greasy lustre, that contains much soda.

Moonstone is an opalescent variety of adularia, having when polished peculiar pearly reflections. *Sunstone* is similar; but contains minute scales of mica. *Aventurine feldspar* often owes its iridescence to minute crystals of hematite, ilmenite, or göthite. *Sunstone* and *moonstone* are mostly oligoclase, and so is a large part of aventurine feldspar.

Diff. Distinguished from the other feldspars by its right-angled cleavage and the absence of striated surfaces.

Obs. One of the constituents of granite, syenyte, gneiss, and other related rocks; also of porphyry, and trachyte; and it often occurs in these rocks in imbedded crystals. St. Lawrence Co., N. Y., affords fine crystals; also Orange Co., N. Y.; Haddam and Middletown, Conn.; Acworth, N. H.; South Royalston and Barre, Mass., etc.; Lenni, Pa. (*Lennilite* and *Delawarite*). Green feldspar occurs at Mount Desert, Me.; an aventurine feldspar at Leiperville, Penn.; adularia at Haddam and Norwich, Conn., and Parsonsfield, Me. A fetid feldspar (sometimes called *Necronite*) is found at Roger's Rock, Essex Co., N. Y.; 21 miles from Baltimore, Md. Carlsbad and Elbogen in Bohemia; Baveno in Piedmont; St. Gothard; Arendal in Norway; Land's End; the Mourne Mountains, Ireland; are some of the more interesting foreign localities. *Cassinite*, from near Media, Pa., contains much intercalated albite.

Felsite is compact, uncleavable orthoclase, having the texture of jasper or flint, which it much resembles. It generally contains disseminated silica. Colors various, as white, gray, brown, red, brownish red and black; sometimes banded. It is distinguished from flint or jasper by its fusibility. It is the material of beds or strata in some rock formations, and also of dikes or masses of eruptive rocks. It is the base of much red porphyry. The vicinity of Marblehead, Mass., is one of its localities.

The name feldspar is from the German word *Feld*, meaning *field*. It is, therefore, wrong to write it *felspar*.

Orthoclase is used extensively in the manufacture of porcelain. The large granite veins of Middletown, Portland, and Branchville, Conn., are quarried in several places for this purpose.

Kaolin. This name is applied to the clay that results from the decomposition of feldspar. See *Kaolinite*, p. 332.

Soda-orthoclase. A monoclinic soda-feldspar from Pantellaria; differing from typical orthoclase in having two thirds atomically of the potassium replaced by sodium.

III. SUBSILICATES.

In the Subsilicates, as stated on page 262, the combining or quantivalent ratio between the bases and silica is 1

to less than 1. In Chondrodite, the first of the following species, the ratio is 4 : 3; in Tourmaline, Andalusite, Cyanite, and Fibrolite, 3 : 2. Analyses of Andalusite obtain 1 of alumina, AlO_3, to 1 of silica, SiO_2, giving the oxygen ratio for bases and silica 3 : 2, which is the composition also of cyanite and fibrolite; the three species, andalusite, cyanite, and fibrolite are the same in constituents and atomic ratio, while differing in crystalline form, exemplifying a case of *trimorphism* among minerals.

The ratio 3 : 2 exists also in Topaz, Euclase and Datolite, in Titanite or sphene, and in Keilhauite. In Staurolite, the ratio is 2 : 1. In datolite and tourmaline the basic constituents include boron; in titanite and keilhauite, titanium; in datolite, euclase, and part of staurolite, hydrogen, that is, the hydrogen of the water found on analysis. In chondrodite, topaz, and some tourmaline, fluorine replaces part of the oxygen.

Chondrodite.—Humite in part (Scacchi's Type II.).

Monoclinic. Cleavage indistinct. Usually in imbedded grains or masses. Color light yellow to brownish yellow, yellowish red, and garnet-red. Lustre vitreous, inclining a little to resinous. Streak white, or slightly yellowish or grayish. Translucent to subtranslucent. Fracture uneven. H. = 6–6·5. G. = 3·1–3·25.

Composition. $Mg_5O_{14}Si_2$ (= $8MgO + 3SiO_2$); but a portion of the magnesium replaced by iron, and a part of the oxygen by fluorine. A specimen from Brewster's, New York, afforded Silica 34·1, magnesia 53·7, iron protoxide 7·3, fluorine 4·1, with 0·5 of alumina = 99·7.

B.B. infusible. Decomposed by hydrochloric acid; solution gelatinizes on evaporation. Reacts for fluorine.

Diff. Unlike tourmaline or garnet, some brownish-yellow varieties of which it approaches in appearance, it does not fuse, and reacts for fluorine. Named from the Greek *chondros*, a grain.

Obs. Abundant in Sussex Co., N. J., and Orange Co., N. Y., occurring at Sparta and Bryam, N. J., and in Warwick and other places in N. Y.; at the Tilly Foster Iron Mine, Brewster's, Putnam County, N. Y., it is very abundant; found also west of Kent, and in Norfolk, Ct.; East Lee, Tyringham, and Hinsdale, Mass. At Vesuvius it occurs in small crystals.

The species was early named *Chondrodite*, from Finland specimens. Afterward, small crystals, found in the lavas of Somma (Vesuvius) were named *Humite*, and both were later referred to the same species. Now three species of different angles and form, but related composition and physical character, are recognized—the above and the following:

Humite. Orthorhombic; embraces part of Humite (Scacchi's Type I.), and some large crystals found at Brewster's, N. Y., and others of Sweden.

Clinohumite. Monoclinic; includes Scacchi's Type III. of Humite, and some of the crystals from Brewster's.

Tourmaline.

Rhombohedral; $R \wedge R = 103°, -\frac{1}{2} \wedge -\frac{1}{2} = 133° 8'$. Usual in prisms of 3, 6, 9, or 12 sides, terminating in a low 3-sided pyramid; sides of the prisms often rounded and striated.

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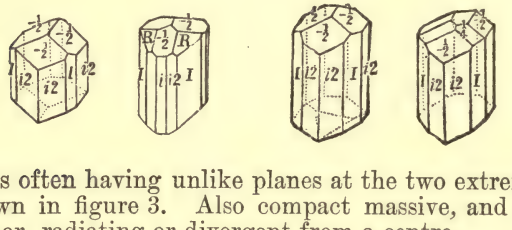


Crystals often having unlike planes at the two extremities, as shown in figure 3. Also compact massive, and coarse columnar, radiating or divergent from a centre.

Color black, blue-black, and dark brown, common; also ruby-red, pale red, rich grass-green, cinnamon-brown, yellow, gray, and colorless. Sometimes red within and green externally, or one color at one extremity and another at the other. Transparent; usually translucent to nearly opaque. Dichroic. Lustre vitreous, inclining to resinous on a surface of fracture. Streak uncolored. Brittle; the crystals often fractured across and breaking very easily. H. = 7·0–7·5. G. = 2·89–3·3.

Composition. $(R_3, B_2, R_2) O_5 Si_2$, in which R includes, in different varieties, Fe, Mg, Na_2, with often traces also of Ca, Mn, K_2, Li_2; R includes aluminium, with some boron in the trioxide state replacing Al; and a little of the oxygen is sometimes replaced by fluorine.

Black, from Haddam, afforded on analysis, Silica 37·50, boron trioxide (by loss) 9·02, alumina 30·87, iron protoxide 8·54, magnesia 8·60, lime 1·33, soda 1·60, potash 0·73, water 1·81 = 100. A red from Paris, Maine, afforded Fluorine 1·19, silica 41·16, boron trioxide (by loss) 8·93, alumina 41·83, manganese protoxide 0·95, magnesia 0·61, soda 1·37, potash 2·17, lithia 0·41, water 2·57 = 100.

Varies in color with the composition; the dark contain much iron and the light colors but little. *Rubellite* is red; *Indicolite* (from *Indigo*) blue and bluish black; *Achroite*, colorless. *Schorl* formerly included the common black tourmaline, but the name is not now used.

The presence of boron trioxide is a remarkable feature of this mineral. The colorless, red, and pale-greenish kinds usually contain lithia. B.B. the darker varieties fuse with ease, and the lighter with difficulty. On mixing the powdered mineral with potassium bisulphate and fluor spar, and heating B.B., the flame becomes green owing to the boron.

Diff. The test for boron is good for all varieties. The dark generally are readily distinguished by the lustre, absence of distinct cleavage, and rather difficult fusibility. The black appear pitch-black on a surface of fracture, and have not the cleavage lines of surfaces characterizing prisms of hornblende. The brown resemble garnet or idocrase, but are less fusible. The red, green, and yellow varieties are distinguished readily by the crystalline form, the prisms of tourmaline always having 3, 6, 9, or 12 prismatic sides (or some multiple of 3). The electric properties of the crystals, when heated, is another remarkable character of this mineral.

Obs. Common in granite, gneiss, mica schist, chlorite schist, steatite, quartzyte, and granular limestone; usually in crystals penetrating the rock. The black crystals are at times a foot long when perhaps of no larger dimensions than a pipe-stem, or even more slender. Has also been observed in sandstones near basaltic or trap dikes. Sometimes penetrating quartz crystals in acicular crystals, like rutile.

Red and green tourmalines, over an inch in diameter and transparent, have been obtained at Paris, Me., besides pink and blue crystals; fine also at Auburn, Hebron, Norway, Rumford, Andover, Me.; also, of much less beauty and size,

at Chesterfield and Goshen, Mass.; black at Norwich, New Braintree, and Carlisle, Mass.; Alsted, Acworth, and Saddleback Mountain, N. H.; Haddam and Monroe, Ct.; Pierpont, Saratoga, Port Henry, and Edenville, N. Y.; Franklin and Newton, N. J.; colorless and brown at Dekalb, N. Y.; transparent brown at Hunterstown, Canada; amber-colored, at Fitzroy; beautiful greenish yellow, at G. Calumet I.; fine cinnamon-brown near Gouverneur, Schroon, Canton, etc., northern N. Y.; Kingsbridge and Amity, Orange Co., N. Y.; and in Sussex Co., N. J.; gray, bluish gray, and green at Edenville, N. Y.; yellowish, bluish, and brownish green at London Grove, and near Unionville, Pa.; black or dark brown, at Orford, N. H.; yellow in E. Marlboro' and W. Marlboro', Pa.; black at Leiperville and Marple, Pa.; thin black plates, in mica, at Grafton, N. H.; Franklin and Newton, Sussex Co., N. J.

The word tourmaline is a corruption of the name used in Ceylon, whence it was first brought to Europe. *Lyncurium* is supposed to be the ancient name for common tourmaline; and the red variety was probably called *hyacinth*.

The red tourmalines, when transparent and free from cracks, are of great value and afford gems of remarkable beauty. They have the richness of color and lustre belonging to the ruby. The yellow tourmaline, from Ceylon, is hardly inferior to the real topaz, and is often sold for that gem. The green specimens, when clear and fine, are also valuable for gems. Plates from pellucid crystals cut in the direction of a vertical plane are much used for polariscopes, and crystals in mica are often thus flattened and ready for such use when not too thin or opaque.

Cappelenite. Yttrium-barium silico-borate, with 14·16 p. c. of silica; hexagonal; brown; G. = 4·4. Norway.

Gehlenite. Tetragonal, like the scapolites in form; color grayish green to brown; G. = 2·9–3·07; formula $Ca_2AlO_{10}Si_2$ with some of the Al replaced by Fe, and some of the Ca by Fe and Mg. Silica about 30 per cent. Mount Monzoni, in the Fassa Valley.

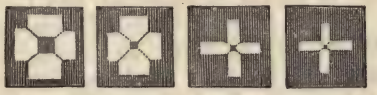
Andalusite.

Orthorhombic; $I \wedge I = 90°\ 48'$. In prisms that are nearly square. Cleavage lateral; sometimes distinct. Also massive; indistinctly coarse columnar, never fine fibrous.

Colors gray and flesh-red, pink. Lustre vitreous, or in-

clining to pearly. Translucent to opaque. Tough. H. = 7·5. G. = 3·1–3·3.

1. 2. 3. 4.



Composition. AlO_5Si = Silica 36·9, alumina 63·1 = 100. B.B. infusible. Ignited after being moistened with cobalt nitrate assumes a blue color. Insoluble in acids.

Chiastolite or *Macle* has an internal tessellated or cruciform structure. Figures 1 to 4 represent sections of crystals from Lancaster, Mass. The structure is owing to carbonaceous impurities distributed, in the crystallizing process, in a regular manner along the sides, edges and diagonals of the crystal. Hardness sometimes as low as 3.

Diff. Distinguished from pyroxene, scapolite, spodumene, and feldspar by its infusibility, hardness, and form.

Obs. Observed only in imbedded crystals. Most abundant in clay slate and mica slate, but occurring also in gneiss. The Tyrol; Saxony; Bavaria; etc.; also in Westford, Mass.; Litchfield and Washington, Ct.; Bangor, Gorham, Standish, Me.; Leiperville, Marple, and Springfield, Pa., at Upper Providence, Pa., one crystal weighing 7 lbs.; as chiastolite at Sterling and Lancaster, Mass.; near Bellows Falls, Vt.; Chowchilla River, Mariposa Co., Cal. First found at Andalusia in Spain.

Fibrolite.—Sillimanite. Bucholzite.

Orthorhombic; $I \wedge I = 96°–98°$. In long, slender rhombic prisms, often much flattened, penetrating the gangue. Cleavage macrodiagonal, brilliant and easy. Also in masses, consisting of aggregated crystals or fibres. Color hair-brown or grayish brown. Lustre vitreous, inclining to pearly. Translucent crystals break easily. H. = 6–7. G. = 3·2–3·3.

Composition. AlO_5Si, as for andalusite, = Silica 36·9, alumina 63·1 = 100. Moistened with cobalt nitrate and ignited assumes a blue color. Infusible alone and with borax.

Diff. Distinguished from tremolite and the varieties generally of hornblende by its brilliant diagonal cleavage, and

its infusibility; from kyanite and andalusite by its brilliant cleavage, its fibrous structure, and its orthorhombic crystalline form.

Obs. Found in gneiss, mica schist, and related metamorphic rocks. Occurs in the Tyrol; at Bodenmais in Bavaria; at the White Mountain Notch in N. H.; at Chester and near Norwich, Ct., both in crystals, fibrous, and fibrous massive; Yorktown, N. Y.; Chester, Birmingham, Concord, Darby, Pa.; in N. Carolina; and elsewhere. Fibrolite was much used for stone implements in Western Europe in the "Stone age;" the locality whence the material was derived is not known.

Davreuxite. Infusible. Probably impure fibrolite.
Dumortierite. A related species, from near Lyons.
Empholite. Infusible, and may belong here. Sweden.

Cyanite.—Kyanite. Disthene.

Triclinic. Usually in long thin-bladed crystals aggregated together, or penetrating the gangue. Sometimes in short and stout crystals. Lateral cleavage distinct. Sometimes fine fibrous.

Color usually light blue, sometimes having a blue centre with a white margin; sometimes white, gray, green, or even black. Lustre of flat face a little pearly. H. = 5–7·5, greatest at the ends of the prisms, and least on the flat face. G. = 3·55–3·7.

Composition. AlO_5Si ($= AlO_3 + SiO_2$), as for andalusite, = Silica 36·9, alumina 63·1 = 100. Blowpipe characters like those of andalusite.

Diff. Distinguished by its infusibility from varieties of the hornblende family. Short crystals have some resemblance to staurolite, but their sides and terminations are usually irregular; they differ also in cleavage and lustre. The thin-bladed habit of cyanite is very characteristic.

Obs. Found in gneiss and mica schist, and often accompanied by garnet and staurolite.

Occurs in long-bladed crystallizations at Chesterfield and Worthington, Mass.; at Litchfield and Washington, Ct.; Windham, Me.; Derby Creek, Delaware Co., and E. Bradford, Chester Co., Pa.; near Wilmington, Del.; and in Buckingham, and Spotsylvania cos., Va.; Chubb's and Crowder's Mts., Gaston Co., N. C. Short crystals (sometimes called

improperly *fibrolite*) occur in gneiss at Bellows Falls, Vt., and at Westfield and Lancaster, Mass.

In Europe, at St. Gothard in Switzerland; at Greiner and Pfitsch in the Tyrol; Styria; Carinthia; Bohemia. Villa Rica in S. America affords fine specimens.

Named from the Greek *kuanos*, a dark-blue substance. Also called *Disthene*, in allusion to the unequal hardness in different directions, and when white, *Rhætizite*.

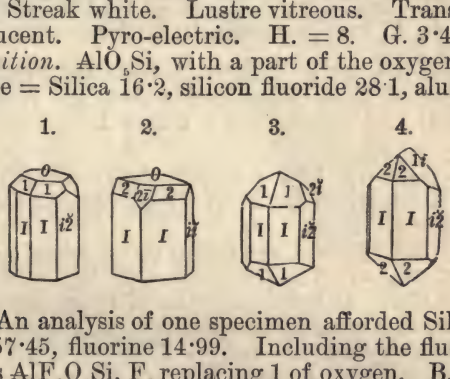
Kyanite is sometimes used as a gem, and has some resemblance to sapphire.

Topaz.

Orthorhombic; $I \wedge I = 124° 17'$. Rhombic prisms, usually differently modified at the two extremities. Cleavage perfect parallel to the base.

Color pale yellow; sometimes white, greenish, bluish, or reddish. Streak white. Lustre vitreous. Transparent to subtranslucent. Pyro-electric. H. = 8. G. 3·4–3·65.

Composition. AlO_5Si, with a part of the oxygen replaced by fluorine = Silica 16·2, silicon fluoride 28·1, alumina 55·7



= 100. An analysis of one specimen afforded Silica 34·24, alumina 57·45, fluorine 14·99. Including the fluorine, the formula is AlF_2O_4Si, F_2 replacing 1 of oxygen. B.B. infusible; some kinds become yellow or of a pink tint when heated; moistened with cobalt nitrate and ignited assumes a fine blue color. Insoluble in acids.

Diff. Readily distinguished from the minerals it resembles by its brilliant and easy basal cleavage.

Obs. Pycnite has a thin columnar structure and forms masses imbedded in quartz. The *Physalite* or *Pyrophysalite* of Hisinger is a coarse, nearly opaque variety, found in yellowish-white crystals of considerable dimensions; intumesces when heated, and hence the name from *phusao*, to blow, and *pur*, fire. Topaz occurs altered to mica (damourite).

Confined to metamorphic rocks or to veins intersecting them, and often associated with tourmaline, beryl, and occasionally with apatite, fluorite, and tin ore.

Fine topazes are brought from the Uralian and Altai mountains, Siberia, and from Kamschatka, where they occur of green and blue colors. In Brazil they are found of a deep yellow color, either in veins or nests in lithomarge, or in loose crystals or pebbles. Sky-blue crystals have been obtained in the district of Cairngorm, in Aberdeenshire. The tin-mines of Schlackenwald, Zinnwald, and Ehrenfriedersdorf in Bohemia, St. Michael's Mount in Cornwall, etc., afford smaller crystals. The physalite variety occurs in crystals of immense size at Finbo, Sweden, in a granite quarry, and at Broddbo. A well-defined crystal from this locality, in the possession of the College of Mines of Stockholm, weighs eighty pounds. Altenberg in Saxony is the principal locality of pycnite; it is there associated with quartz and mica.

At Stoneham, Me., in fine crystals; Trumbull, Ct., in large coarse crystals, sometimes 6 to 7 in. through, and rarely small and transparent; Pike's Peak, Col., in fine crystals, some affording cut stones 10 to 193 carats each; also in Chalk Mt. and Nathrop, Col., in rhyolyte; in Utah, in rhyolyte, 40 m. N. of Sevier Lake; Arizona; Oregon, in gold-washings.

The ancient *topazion* was found on an island in the Red Sea, which was often surrounded with fog, and therefore difficult to find. It was hence named from *topazō*, to seek. This name, like most of the mineralogical terms of the ancients, was applied to several distinct species. Pliny describes a statue of Arsinoë, the wife of Ptolemy Philadelphus, four cubits high, which was made of topazion, or topaz, but evidently not the topaz of the present day, nor chrysolite, which has been supposed to be the ancient topaz. It has been conjectured that it was a jasper or agate; others have supposed it to be prase or chrysoprase.

Topaz is employed in jewelry, and for this purpose its color is often altered artificially by heat. The variety from Brazil assumes a pink or red hue, so nearly resembling the Balas ruby, that it can only be distinguished by the facility with which it becomes electric by friction. Beautiful crystals for the lapidary are brought from Minas Novas, in

Brazil. From their peculiar limpidity, topaz pebbles are sometimes denominated *gouttes d'eau*.

On account of the perfect cleavage, topaz is a poor substitute for emery.

Euclase.

Monoclinic. In oblique rhombic prisms, with cleavage highly perfect parallel to the clinodiagonal section, affording smooth polished faces.

Color pale green to white or colorless, pale blue. Lustre vitreous; transparent. Brittle. H. = 7·5. G. = 3·1. Pyro-electric.

Composition. $H_2\frac{2}{3}Be_2AlO_{10}Si_2$ = Silica 41·20, alumina 35·22, glucina 17·39, water 6·19 = 100. B.B. fuses with much difficulty to a white enamel; not acted on by acids.

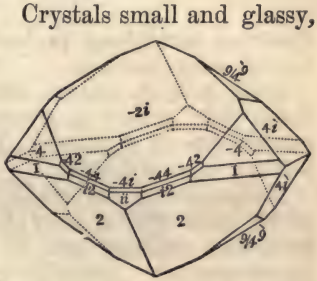
Diff. The cleavage of this glassy mineral is very perfect, like that of topaz, but is not basal.

Obs. The Ural; Tyrol; with topaz in Brazil.

The crystals are elegant gems of themselves, but are seldom cut for jewelry on account of their brittleness.

Datolite.—Datholite. Humboldtite.

Monoclinic; $I \wedge I = 115° 3'$. Crystals small and glassy, without distinct cleavage. Also botryoidal, and columnar within (*botryolite*); also massive and porcelain-like in fracture. Color white, occasionally grayish, greenish, yellowish, or reddish. Translucent. H. = 5–5·5. G. = 2·9–3.



Composition. $H_2Ca_2B_2O_{10}Si_2$ = Silica 37·5, boron trioxide 21·9, lime 35·0, water 5·6 = 100. Botryolite contains twice the proportion of water. B.B. becomes opaque, intumesces and melts easily to a glassy globule coloring the flame green. Decomposed by hydrochloric acid; the solution gelatinizes on evaporation.

Diff. Its glassy complex crystallizations, without cleavage, distinguish it from other minerals that gelatinize with acid; so also its tingeing the blowpipe-flame green.

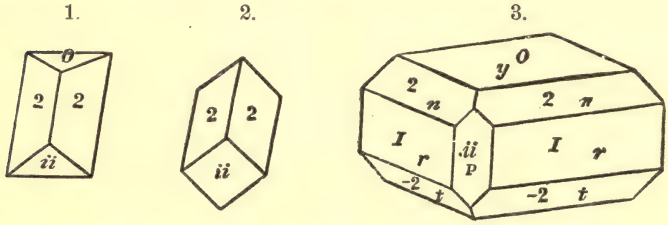
Obs. Occurs in cavities in trap rocks, or the adjoining sandstone, and in gneiss. Found in Scotland; at Andreas-

berg; Baveno; Toggiana. Also at Bergen Hill, N. J.; at Roaring Brook, 14 miles from New Haven; and near Hartford, Berlin, Middlefield Falls, Meriden, Tariffville, Ct.; in great abundance at Eagle Harbor in the copper region, Lake Superior, both in crystals and massive; on Isle Royale; near San Carlos, Cal.

Homilite. A black silicate of iron and calcium, like datolite in its crystals; resembles gadolinite, but affords 15 to 18 per cent. of boracic acid with 32 of silica; formula $R_3B_2O_{10}Si_2$. Brevig, Norway.

Titanite.—Sphene.

Monoclinic; $I \wedge I = 113° 31'$, $2 \wedge 2 = 136° 12'$; crystals usually very oblique thin-edged prisms. Cleavage in one



direction sometimes perfect, owing to twin-composition. Occasionally massive.

Color grayish brown, ash-gray, brown to black; sometimes pale yellow to green. Streak uncolored. Lustre adamantine to resinous. Transparent to opaque. H. = 5–5·5. G. = 3·4–3·56.

Composition. $CaTiO_5Si$ = Silica 30·6, titanium dioxide 40·82, lime 28·57 = 100; in dark brown and black crystals, some iron replaces part of the calcium. B.B. fuses with intumescence. Imperfectly decomposed by hydrochloric acid.

The dark varieties of this species were formerly called *titanite*, and the lighter *sphene*. Named *sphene* from the wedge-shaped crystals, from the Greek *sphen*, wedge. *Greenovite* is a variety colored rose-red by manganese. *Leucoxene* and *Titanomorphite* are probably titanite(p. 453).

Diff. The thin wedge-like form of the crystals is generally a distinguishing character; but some crystals are of other forms.

Obs. Occurs mostly in disseminated crystals in granite,

gneiss, mica schist, syenyte, or granular limestone. Usually associated with pyroxene and scapolite, and often with graphite. Has been found in volcanic rocks. Crystals are commonly $\frac{1}{4}$ to $\frac{1}{2}$ an inch long; but sometimes very large.

Foreign localities are Arendal in Norway; St. Gothard, Mont Blanc; Tyrol; Piedmont; Argyleshire and Galloway, Great Britain. Occurs at Roger's Rock, on Lake George, with graphite and pyroxene, at Gouverneur, near Natural Bridge in Lewis Co. (the variety called *Lederite*), in Monroe, Edenville, Warwick, and Amity, in Orange Co., near Peekskill in Westchester County, and near West Farms, N. Y.; Lee, Bolton, and Pelham, Mass.; Trumbull, Ct.; Sanford and Thomaston, Me.; Franklin, N. J.; near Attleboro', Bucks Co., Pa.; at Dixon's quarry, 7 miles from Wilmington, Del.; 25 miles from Baltimore, Md., on the Gunpowder; Renfrew, Canada, in enormous crystals, one weighing 72 pounds.

Alshedite, from Sweden, is probably brown and gray titanite.

Guarinite. Like sphene in composition, but orthorhombic.

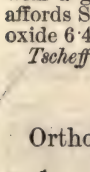
Keilhauite, or *Yttro-titanite*. Related to sphene; brownish black, with a grayish brown powder; G. = 3·69; H. = 6 5; fuses easily; affords Silica 30·0, titanic acid 29·0, yttria 9·6, lime 18·9, iron sesquioxide 6·4, alumina 6·1; also contains scandium. Arendal, Norway.

Tscheffkinite. Near Keilhauite. Illmen Mountains.

Staurolite.—Staurotide.

Orthorhombic; $I \wedge I = 129°\ 20'$. Cleavage imperfect. Usually in cruciform twin crystals. Figure 2, common; another crosses at an acute angle near 60°; another, of rare occurrence, consists of three crystals intersecting at angles near 60°. Never in massive forms or slender crystallizations.

1.



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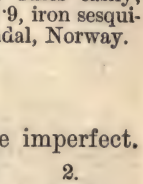


Color brown to black. Lustre vitreous, inclining to resinous; sometimes bright, but often dull. Translucent to opaque. H. = 7–7·5. G. = 3·4–3·8; purest, 3·7–3·8.

Composition. $(\frac{1}{5}R_3\frac{4}{5}Al)_4O_{18}Si_3$, in which R = iron with a little magnesium, and occasionally manganese, with some hydrogen of basic water. Silica 28·3, alumina 51·7, iron protoxide 15·8, magnesia 2·5, water 1·7 = 100. B.B. infusible, excepting a manganesian variety. Insoluble in acids.

Diff. Distinguished from tourmaline and garnet by its infusibility and form.

Obs. Found in crystals in mica schist and gneiss.

Very abundant through the mica schist of New England: Grantham, Cabot, Windham, Me.; Franconia, Lisbon, N. H.; Chesterfield, Mass.; Bolton, Tolland, Salisbury, Ct; on the Wissahickon, 8 m. from Philadelphia; in Cherokee, Madison and Clay cos., N. C.; at Canton, and in Fannin Co., Ga., in handsome twins. Mt. Campione in Switzerland, and the Greiner Mountain, Tyrol, are noted foreign localities.

Named staurolite from the Greek *stauros*, a cross.

Schorlomite. Black, and often irised tarnished; streak grayish black; H. = 7-7·5; G. = 3·80; fuses readily on charcoal; easily decomposed by the acids, and gelatinizes; contains much titanium, with iron, lime, and silica. Magnet Cove, Ark.; Kaiserstuhlgebirge, Breisgau. Makes a black gem of submetallic lustre.

Zunyite. In tetrahedrons, often transparent, and massive; lustre vitreous; H. = 7; G. = 2·875; analysis afforded Silica 24·33, alumina 57·88, water (basic) 10·89, fluorine 5·61, chlorine 2·91, with a little Fe_2O_3, K_2O, Na_2O, Li_2O. The Zuñi Mine, San Juan Co., Col.

B. HYDROUS SILICATES.

The three sections under which the Hydrous Silicates are arranged are the following:

I. General Section. Includes: (1) *Bisilicates*—Pectolite, Laumontite, Apophyllite, etc.; (2) *Unisilicates*—Prehnite, Calamine, etc.; and (3) *Subsilicates*—as Allophane, and some related species.

II. Zeolite Section. Includes minerals which are feldspar-like in constituents, and apparently so in quantivalent (or oxygen) ratio; the basic elements being, as in the feldspars, (1) aluminium, and (2) the metals of the alkalies K, Na, and of the alkaline earths Ca, Ba, with also Sr, to the almost total exclusion of magnesium and iron.

III. Margarophyllite Section. Embraces species having a micaceous or thin-foliated structure when crystallized, with the surface of the folia pearly, and the plane angle of the base of the prism 120°. Whether crystallized or massive, the feel is greasy, at least when pulverized. It comprises (1) Bisilicates: including Talc and Pyrophyllite, which are atomically and physically similar species, although the former is a magnesium silicate, and the latter

an aluminium silicate; (2) Non-alkaline Unisilicates, including Kaolinite and Serpentine, which have a similar difference in constituents to the preceding with the same likeness in composition, and, also, some related species; (3) Alkaline Unisilicates: as, Pinite and the Hydrous Micas, which are species containing potassium or sodium as an essential constituent; (4) the Chlorite Group, the species of which are mostly Subsilicates and non-alkaline.

I. GENERAL SECTION.

Pectolite.

Monoclinic, isomorphous with wollastonite. Usually in aggregations of acicular crystals, or fibrous-massive, radiate, stellate. Color white, or grayish. Translucent to opaque. Tough. H. = 5. G. = 2·86–2·88.

Composition. RO_3Si, in which $R = \frac{1}{6}H_2\frac{1}{6}Na_2\frac{4}{6}Ca$, = Silica 54·2, lime 33·8, soda 9·3, water 2·7 = 100. In the closed tube yields water. B.B. easily fusible. Decomposed by hydrochloric acid, and the solution gelatinizes on evaporation.

Resembles fibrous varieties of tremolite, natrolite, thomsonite, wollastonite.

Obs. Occurs mostly in cavities or seams in trap or basic eruptive rocks, and occasionally in other rocks. Found at Ratho Quarry, Edinburgh, Scotland (*Ratholite, Walkerite*); at Kilsyth; Isle of Skye; the Tyrol; Bergen Hill, N. J.; compact at I. Royale, L. Superior, and near Point Barrow, Alaska.

Okenite. Gyrolite. Related hydrous calcium silicates. Okenite is from the Faröe Islands, Iceland, and Greenland, and gyrolite from the Isle of Skye, and from Nova Scotia 25 m. S. W. of Cape Blomidon. *Tobermorite*, from Isle of Mull, is near gyrolite.

Laumontite.

Monoclinic; $I \wedge I = 86° 16'$. Near pyroxene in form. Cleavage: clinodiagonal, and parallel to *I*, perfect. Also massive, with a radiating or divergent structure; not fine fibrous.

Color white, passing into yellow or gray, sometimes red. Lustre vitreous, inclining to pearly on the cleavage face. Transparent to translucent. H. = 3·5–4. G. = 2·25–2·36. Becomes opaque on exposure through loss of water, and readily crumbles.

Composition. $CaAlO_{1/2}Si_4 + 4$ aq = Silica 50·0, alumina 21·8, lime 11·9, water 16·3 = 100. B.B. swells up and fuses easily to a white enamel. Decomposed by hydrochloric acid, and the solution gelatinizes on evaporation.

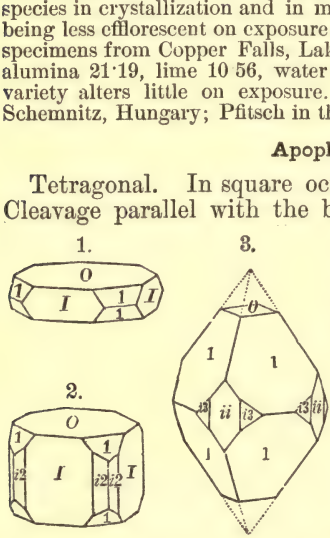
Diff. The alteration this species undergoes on exposure to the air at once distinguishes it. This result may be prevented with cabinet specimens by dipping them into a solution of gum-arabic.

Obs. Found in the veins and cavities of trap-rocks and also in gneiss, porphyry. Occurs at the Faröe Islands; Kilpatrick Hills, near Glasgow; Disco, Greenland; St. Gothard, Switzerland; Peter's Point, N. Scotia; Phippsburg, Me.; Charlestown syenyte quarries, Mass.; Bergen Hill, N. J.; the Copper region, L. Superior, and Isle Royale.

Leonhardite. Probably Laumontite which has lost part of its water by alteration—the part that goes off below 212° F. Resembles that species in crystallization and in most of its characters, but differs in being less efflorescent on exposure to a dry atmosphere. Analyses of specimens from Copper Falls, Lake Superior, obtained, Silica 55·50, alumina 21·19, lime 10·56, water 11·93 = 99·68. The Copper Falls variety alters little on exposure. Reported also from trachyte at Schemnitz, Hungary; Pfitsch in the Tyrol.

Apophyllite.

Tetragonal. In square octahedrons, prisms, and tables. Cleavage parallel with the base highly perfect. Massive and foliated. Color white or grayish; sometimes with a shade of green, yellow, or red. Lustre of *O* pearly: of the other faces vitreous. Transparent to opaque. H. = 4·5–5. G. = 2·3–2·4.



Composition. Silica 52·97, lime 24·72, potash 5·20, water 15·90, fluorine 2·10 = 100·89. B.B. exfoliates, colors the flame violet (owing to the potash), and fuses very easily to a white enamel. In the closed tube yields water which has an acid reaction. Decomposed by hydrochloric acid with the separation of slimy silica.

Diff. The easy basal cleavage and basal pearly lustre, and the forms of its crystals, distinguish it from the preceding

species. The prisms are sometimes almost cubes, with the angles cut off by the planes of the pyramid; but the difference in the lustre of the prismatic and basal faces shows that it is tetragonal. It is never fibrous.

The name alludes to its exfoliation before the blowpipe.

Obs. Found in amygdaloidal trap and basalt.

Fine crystallizations at Peter's Point and Partridge Island, N. Scotia; Bergen Hill and Weehawken, N. J.; Cliff Mine, L. Superior region.

Catapleiite. Hydrous zirconium sodium silicate. Norway.

Dioptase and *Chrysocolla.* Hydrous copper silicates. See p. 156.

Picrosmine, Pyrallolite, Picrophyll, Traversellite, Pitkarandite, Strakonitzite, Monradite, are names of varieties of pyroxene in different stages of alteration. *Xylotine* and *Pilolite* are probably altered asbestus.

Leidyite. A hydrous bisilicate of Al, Fe, Mg, Ca; in silky greenish scales. From Leiperville, Pa.

Prehnite.

Orthorhombic; $I \wedge I = 99° 56'$. Cleavage basal. Sometimes in six-sided prisms, rounded so as to be barrel-shaped, and looking as if made up of a series of united plates; also in thin rhombic or hexagonal plates. Usually reniform and botryoidal, with a crystalline surface. Never fibrous.

Color apple-green to colorless. Lustre vitreous, except the face *O*, which is somewhat pearly. Subtransparent to translucent. H. = 6–6·5. G. = 2·8–2·96.

Composition. $H_2Ca_2Al_2O_{12}Si_3$ = Silica 43·6, alumina 24·9, lime 27·1, water 4·4 = 100. B.B. fuses very easily to an enamel-like glass. Decomposed by hydrochloric acid, leaving a residue of silica, but does not gelatinize. Yields a little water when heated in a closed tube.

Diff. Distinguished from beryl, green quartz, and chalcedony by fusing B.B., and from the zeolites by its hardness.

Obs. Found in the cavities of trap, gneiss, and granite.

Occurs in trap in the Connecticut Valley, and at Paterson and Bergen Hill, N. J.; in gneiss at Bellows Falls, Vt.; in syenyte at Charlestown, Mass.; and very abundant, forming large veins, in the Copper region of Lake Superior, 3 miles south of Cat Harbor, and elsewhere, where the greenish variety called *Chlorastrolite* and *Zonochlorite* is found.

The Fassa Valley in the Tyrol, St. Christophe in Dauphiny, and the Salisbury Crag, near Edinburgh, are some of the foreign localities.

Prehnite receives a handsome polish, and is sometimes used for inlaid work. In China it is polished for ornaments, and large slabs have been cut from masses brought from there.

Gismondite (*Zeagonite*). A hydrous calcium-aluminium silicate, occurring in twinned crystals. Found in lava at Capo di Bove, near Rome; also near Görlitz.

Edingtonite. Tetragonal; a hydrous barium-aluminium silicate. The Kilpatrick Hills, with harmotome.

Carpholite. A manganese-aluminium silicate; in silky, yellow, radiated tufts. Tin-mines of Schlackenwald.

Pilinite. A hydrous calcium-aluminium silicate; in fibrous felt-like crusts; B.B. fuses easily; insoluble in hot acid. Silesia.

Matricite. Hydrous magnesium silicate; gray; infusible. Wermland, Sweden.

Pyrosmalite. A manganese-iron silicate and chloride. Sweden.

Calamine. A hydrous zinc unisilicate; see p. 174.

Villarsite is probably altered chrysolite; see p. 277.

Cerite, *Tritomite*, are cerium and lanthanum silicates. *Thorite* (*Orangite*), *Eucrasite*, *Erdmannite*, and *Freyalite* are thorium silicates. *Kainosite*, an yttrium, etc., silicate.

Uranothorite. A thorite containing uranium; dark red-brown; infusible. Champlain iron region, Northern New York.

Allophane.

In amorphous incrustations, with a smooth small-mammillary surface, and often hyalite-like, and sometimes pulverulent. Color pale bluish white to greenish, and deep green; also brown, yellow, colorless. Translucent. H. = 3. G. = 1·85–1·89.

Composition. Mostly $Al_2O_3Si + 6$ (or 5) aq. Silica 23·75, alumina 40·62, water 35·63 = 100. In the closed tube yields much water. B.B. infusible, but crumbles. A blue color with cobalt solution, and a jelly with hydrochloric acid.

Occurs in Saxony; a copper-mine in Bohemia; with limonite in Moravia; Chessy Copper Mine near Lyons; in Old Chalk Pits near Woolwich, England; with gibbsite in limonite beds in Richmond, Mass.; at the copper-mine of Bristol, Conn.; at Morgantown, Pa.; copper-mines of Polk County, Tenn.; Lawrence Co., Ind.

Sulphatallophane. A mixture of allophane and a basic aluminium sulphate.

Collyrite. A hydrous aluminium silicate containing only 14 to 15 per cent. of silica, and 35 to 40 of water; and *Schrötterite* is another with 11 to 12 per cent. of silica. The latter has been reported as occur-

ring as a gum-like incrustation, at the falls of Little River, on Sand Mountain, Cherokee County, Alabama. *Scarbroite* is a related mineral of doubtful nature.

Leucotile. A hydrous subsilicate. On serpentine. Silesia.

Chalcomorphite. Hexagonal with basal cleavage; affords only 25·4 p. c. of silica, with alumina, lime, and soda. Lake Laach; The Eiffel.

II. ZEOLITE SECTION.

The species of the Zeolite Section have been described as having some relation to the feldspars in constitution. In the feldspars, as explained on page 273, the following oxygen ratios, for the protoxides, alumina, and silica, are the common ones: 1 : 3 : 4, 1 : 3 : 6, 1 : 3 : 8, 1 : 3 : 9, 1 : 3 : 10, 1 : 3 : 12. So, among the zeolites, if the water be left out of consideration, these are the ratios: 1 : 3 : 4 (in Thomsonite), 1 : 3 : 6 (Natrolite, Scolecite, etc.), 1 : 3 : 8 (Analcite, Chabazite, etc.), 1 : 3 : 10 (Harmotome), 1 : 3 : 12 (Stilbite, Heulandite, etc.). This fact, added to the absence or nearly total absence of magnesium and iron, and presence, instead, of Na_2, K_2, Ca, Ba, make out a distinct relation to the feldspars, whatever may be the part which the water sustains in the compounds. Besides barium, strontium is sometimes present, an element not yet known to characterize a species of feldspar.

These minerals were called *zeolites* because they generally fuse easily with intumescence before the blowpipe, the term being derived from the Greek *zeo*, to boil. Among those described beyond, Heulandite and Stilbite have a strong pearly cleavage, and the latter is often in pearly radiations; Natrolite, Scolecite, are fibrous and radiated, or in very slender prisms; Thomsonite occurs either radiated, or compact, or in short crystals; while Harmotome, Analcite, and Chabazite, and the related Gmelinite, occur only in short or stout glassy crystals, those of chabazite looking sometimes like cubes, and of analcite, like trapezohedral garnets in form.

The zeolites are sometimes called *trap* minerals, because they are often found in the cavities or fissures of amygdaloidal trap as well as related basic eruptive rocks. Yet they occur also occasionally in fissures or cavities in gneiss, granite, and other metamorphic rocks. They are not the original minerals of any of these rocks; but the results of alteration of portions of them near the little cavities or fis-

sures in which the minerals occur; and part were made while the rock was still hot, and as cooling went forward. Besides true zeolites, such cavities often contain also Laumontite (p. 293), noted for its tendency to crumble on exposure; Pectolite and Okenite (p. 293), which are fibrous like Natrolite and Scolecite; Apophyllite (p. 294), having one pearly cleavage like heulandite and stilbite; Prehnite (p. 295), usually apple-green; Datolite (p. 289), in stoutish glassy complex crystals, or in smooth botryoidal forms; Aragonite (p. 218), sometimes radiated fibrous, and Calcite (p. 215) with its three directions of like easy cleavage, and effervescing with hydrochloric acid; Siderite (p. 185), in spheroidal or other forms; Chlorite (p. 316), granular massive, of a dark olive-green color; and Quartz, either in crystals, or as chalcedony, agate, or carnelian, and in either case easily distinguished by the hardness, absence of cleavage, and infusibility. Of all these species Calcite and Quartz are the most common. Of rarer occurrence than the above, there are Orthoclase, Asphaltic coal, Copper, etc.

All the zeolites yield water in the closed tube, and many of them gelatinize with hydrochloric acid.

Thomsonite.

Orthorhombic; $I \wedge I = 90° 26'$. In right rectangular prisms. Usually in masses having a radiated structure within, and consisting of long fibres, or acicular crystals; also amorphous. Color snow-white; impure varieties brown. Lustre vitreous, inclining to pearly. Transparent to translucent. H. = 5–5. Brittle. G. = 2·3–2·4.

Composition. $(Ca, Na_2)AlO_3Si_2 + 2\frac{1}{2}$ aq = Silica 38·09, alumina 31·62, lime 12·60, soda 4·62, water 13·40 = 100·20. B.B. fuses very easily to a white enamel. Decomposed by hydrochloric acid; solution gelatinizes on evaporation.

Diff. Distinguished from natrolite by its fusion to an opaque and not to a glassy globule.

Obs. Occurs in amygdaloid, near Kilpatrick, Scotland; at the Faröe Ids. (*Mesole* or *Faröelite*) in spherical, lamellar radiated, and pearly within; in lavas at Vesuvius (*Comptonite*); in clinkstone in Bohemia; the Tyrol, etc.; at Peter's Point, Nova Scotia, in trap; a massive variety (*Ozarkite*) at Magnet Cove, Ark.; at Grand Marais, L. Superior, massive

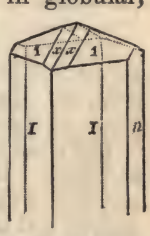
and in hard nodules, radiated within, which have much beauty when polished, and are used in jewelry.

The species was named after Dr. Thomas Thomson, of Glasgow.

Hydronephelite. White; H. = 4.5; gelat. Litchfield, Me., from alteration of sodalite.

Natrolite.

Orthorhombic; $I \wedge I = 91°$; $1 \wedge 1$ over $x = 143°\ 20'$. Prisms very slender and aggregated. Also in globular, stellated, and divergent groups of delicate acicular fibres, the fibres often terminating in acicular prismatic crystals.



Color white, or inclining to yellow, gray, red. Lustre vitreous. Transparent to translucent. H. = 5–5·5. G. = 2·245–2·25. Brittle.

Composition. $Na_2AlO_{10}Si_3 + 2$ aq = Silica 47·29, alumina 26·06, soda 16·30, water 9·45 = 100. B.B. fuses easily and quietly to a clear glass; a fine splinter melts in a candle flame. Decomposed by hydrochloric acid; the solution gelatinizes on evaporation.

Diff. Distinguished from scolecite by its quiet fusion, and also by the characters mentioned below.

Obs. Found in amygdaloidal trap, basalt and volcanic rocks; sometimes in seams in granitic rocks. Named from *natron*, soda.

Occurs in Bohemia; Auvergne; Fassathal, Tyrol; at Glen Farg in Fifeshire; in Dumbartonshire; Nova Scotia; Bergen Hill and Weehawken, N. J.; Copper region, Lake Superior.

Scolecite. Resembles natrolite, and differs in containing *lime* in place of *soda*; also in having its slender rhombic glassy prisms longitudinally twinned, as is shown by the meeting of two ranges of striæ at an angle along or near the central line of opposite prismatic planes; crystallization either monoclinic or triclinic; lustre vitreous, or a little pearly; B.B. curls up like a worm (whence the name from the Greek *skolēx*, a *worm*) and then melts. Staffa; Faröe; Iceland; Finland; Hindostan; Liguria; Fellinen Alp.

Mesolite. A related species, similar in its acicular forms; monoclinic or triclinic. Includes *Antrimolite* and *Harringtonite.* Occurs on Faröe, at Giant's Causeway, near Edinburgh, etc.; in N. Scotia at C. Blomidon.

Pseudonatrolite. Resembles natrolite; fuses less easily. Elba, in granite.

Analcite.

Isometric. Usually in trapezohedrons (Fig. 1, also Fig. 2).

The appearance sometimes seen in polarized light is shown in Fig. 14, page 79. Often colorless and transparent; also milk-white, grayish and reddish white, and sometimes opaque. Lustre vitreous. H. = 5–5·5. G. = 2·25.

Composition. $Na_2AlO_{12}Si_4 + 2\,aq$ = Silica 54·47, alumina 23·29, soda 14·07, water 8·17 = 100. B.B. fuses easily to a colorless glass. Decomposed by hydrochloric acid; the silica separates in gelatinous lumps.

Diff. Characterized by its crystallization, and absence of cleavage. Distinguished from quartz and leucite by giving water in a closed glass tube; from calcite by its fusibility, and by not effervescing with acids; from chabazite and its varieties by fusing *without* intumescence to a *glassy* globule, and by the crystalline form.

Obs. Found in cavities and seams in amygdaloidal trap, basalt and other eruptive rocks, and sometimes in granite, syenyte, and gneiss.

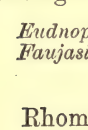
Occurs in fine crystallizations in Nova Scotia; also at Bergen Hill, N. J.; Perry, Me.; in the trap of the Copper region, Lake Superior; and near Montreal, Canada. The Faröe Islands; Iceland; Glen Farg, near Edinburgh; Kilmalcolm, the Campsie Hills, and Antrim; the Vicentine; the Hartz at Andreasberg; Sicily, and Vesuvius.

The name *analcite* is from the Greek, *analkis*, weak, alluding to its weak electric power when heated or rubbed.

Eudnophite. Near analcite. Norway.
Faujasite. In isometric octahedrons. The Kaiserstuhl, Baden.

Chabazite.

Rhombohedral; $R : R = 94° 46'$. Often in rhombohedrons, much resembling cubes; also in complex twins. Cleavage parallel to *R*. Never mssivae or fibrous.



Color white; yellowish; flesh-red or red (*Acadialite*). Lustre vitreous. Transparent to translucent. H. = 4–5. G. = 2·08–2·19.

Composition. $CaAlO_{12}Si_4 + 6$ aq, with a little Na_2 or K_2 in place of part of the Ca. The Nova Scotia acadialite afforded Silica 52·20, alumina 18·27, lime 6·58, soda and potash 2·12, water 20·52. B.B. intumesces and fuses to a nearly opaque bead. Decomposed by hydrochloric acid, with the separation of slimy silica. In the closed tube gives water. *Phacolite* is a variety in complex glassy crystals.

Diff. The nearly cubical form often presented by the crystals of chabazite is a striking character. It is distinguished from analcite as stated under that species; from calcite by its hardness and action with acids; from fluorite by its form and cleavage, and its showing no phosphorescence.

Obs. Found in trap and occasionally in gneiss, syenyte, and other rocks. From the Faröe Ids.; Giant's Causeway, Antrim; Isle of Skye; Bohemia (*Phacolite*); Poonah in India. The trap of Connecticut Valley, but in poor specimens; at Hadlyme and Stonington, Conn.; Charlestown, Mass.; Bergen Hill, N. J.; Piermont, N. Y.; Jones's Falls, near Baltimore (*Haydenite*); fine in Nova Scotia, both white crystals, and also red (*Acadialite*) in abundance.

Herschelite. Near chabazite in form; formula $(\frac{1}{2}Na_2\frac{1}{2}Ca)AlO_{12}Si_4 + 6$ aq. Richmond, in Victoria, Australia; Sicily.

Gmelinite. Closely resembles some chabazite, but its crystals are usually hexagonal rather than rhombohedral in appearance; formula $(Na_2, Ca)AlO_{12}Si_4$; a Bergen Hill specimen afforded Silica 48·67, alumina 18·72, lime 2·60, soda 9·14, water 21·35 = 100·48; gelatinizes with hydrochloric acid, but in other respects resembles chabazite. Andreasberg; Antrim, Ireland; Skye; Bergen Hill, N. J.; Nova Scotia, at Cape Blomidon (*Ledererite*). Named after the chemist Gmelin. *Groddeckite* is a variety.

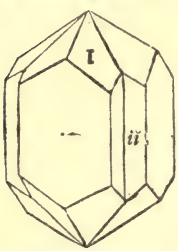
Levynite (*Levyne*). Rhombohedral, somewhat resembling gmelinite in its crystals; the water excluded, having the quantivalent ratio of labradorite, 1 : 3 : 6; colorless, white, grayish, reddish. Iceland; Greenland; Antrim; Londonderry; Hartfield Moss near Glasgow. Named after the crystallographer, Lévy.

Harmotome.

Monoclinic. Unknown except in compound crystals; and commonly in forms similar to the annexed figure; also in compound rhombic prisms.

Color white; sometimes gray, yellow, red, or brownish. Subtransparent to translucent. Lustre vitreous. H. = 4·5. G. = 2·45.

Composition. $BaAlO_{14}Si_5 + 5$ aq = Silica 46·5, alumina 15·9, baryta 23·7, water 13·9 = 100; but a little of the baryta replaced by potash. B.B. whitens, crumbles, and fuses quietly to a white translucent glass. Gives water in a closed glass tube. Partially decomposed by hydrochloric acid, and if sulphuric acid be added to the solution, a heavy white precipitate of barium sulphate is formed. Some varieties phosphoresce when heated.



Diff. Its twin crystals, when distinct, cannot be mistaken for any other species except phillipsite. Much more fusible than glassy feldspar or scapolite; does not gelatinize like thomsonite.

Obs. In amygdaloidal trap, and in trachyte and phonolyte; also in gneiss, and metalliferous veins. Fine at Strontian in Scotland (*Morvenite*), and in Dumbartonshire; Andreasberg in the Hartz; Kongsberg in Norway. Has been found in seams in the gneiss in the upper part of New York Island.

Named harmotome from the Greek *harmos*, a joint, and *temno*, I cleave.

Phillipsite. Near harmotome in its cruciform crystals and other characters, but differing in containing lime in place of baryta; differs also in gelatinizing with acids and in fusing with some intumescence; also occurs in sheaf-like aggregations and in radiated crystallizations. The Giant's Causeway; Capo di Bove; Vesuvius; Sicily; Iceland.

Bravaisite. Hydrous silicate of aluminium, potassium, magnesium and iron. Coal shales of Noyant, France.

Stilbite.

Monoclinic. In prisms like the figure, flattened parallel to the face *i-ĭ*, which is the direction of cleavage; $1 \wedge 1 = 119° 16'$, and 114°. Also in sheaf-like aggregations, and spheres, thin pearly lamellar-columnar in structure; also in radiated crystallizations; never fine fibrous.

Color white; sometimes yellow, brown, or red. Subtransparent to translucent. Lustre highly pearly on cleavage surface. H. = 3·5–4. G. = 2·1–2·15.

Composition. $CaAlO_{16}Si_6 + 6$ aq = Silica 57·4, alumina 16·5, lime 8·9, water 17·2 = 100; but with a little Na_2 or K_2 in place of part of the Ca. B.B. exfoliates, swells up, and

curves into fan-like forms, and fuses to a white enamel. Decomposed by hydrochloric acid without gelatinizing.

Diff. Cannot be scratched with the thumb-nail, like gypsum. Unlike heulandite in its crystals.

Obs. Occurs mostly in trap or basaltic rocks; also on gneiss and granite. Found on the Faröe Ids.; Isle of Skye; Isle of Arran, and elsewhere, Scotland; Andreasberg, Hartz; the Vendayah Mts., Hindostan. Found sparingly at the Chester and Charlestown syenyte quarries, Mass.; at New Haven, Thatchersville and Hadlyme, Ct., and other points in the Connecticut Valley trap; at Phillipstown, N. Y.; Bergen Hill, N. J.; in the copper region of Lake Superior; in beautiful crystallizations at various points in Nova Scotia.

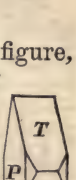
The variety in spheres (*spherostilbite*) occurs in I. Skye; Elba; in the U. States, in Tyringham, Mass.; in N. Scotia.

Named stilbite from the Greek *stilbè* lustre. Has also been called *Desmine*, and in Germany *Heulandite*, where heulandite has been called *stilbite*.

Foresite. From Elba, in minute crystals on tourmaline.

Heulandite.

Monoclinic. In right rhomboidal prisms like the figure, with perfect pearly cleavage parallel to P, and other planes vitreous in lustre. $P \wedge M$ or $T = 90°$; $M \wedge T = 129° 40'$. Color white; sometimes reddish, gray, brown. Transparent to subtranslucent. Folia brittle. H. = 3·5–4. G. = 2·2.



Composition. $CaAlO_{16}Si_6 + 5$ aq = Silica 59·1, alumina 16·9, lime 9·22, water 14·8 = 100. Contains 1 to 2 per cent. of Na_2 or K_2 in place of part of the Ca. Blowpipe characters like those of stilbite. Intumesces and fuses, and becomes phosphorescent. Dissolves in acid without gelatinizing.

Diff. The very pearly lustre of the cleavage face is a marked characteristic. Distinguished from gypsum by its hardness; from apophyllite and stilbite by its crystals; and from the latter species also in not occurring in radiated, sheaf-like or spherical crystallizations.

Obs. Found in cavities and fissures in trap; occasionally in gneiss, and in some metalliferous veins; in large crystallizations at Berufiord, Iceland; and Vendayah Mts., Hindostan; also at Isle Skye; near Glasgow; Fassa Valley;

Elba (*Oryzite*); at Bergen Hill, N. J., in trap; at Hadlyme, Ct., and Chester, Mass., on gneiss; Leiperville, Pa.; near Baltimore, on hornblende schist (*Beaumontite*); at Peter's Point and Cape Blomidon, and other places in Nova Scotia, in trap.

Named by Brooke after Mr. Heuland, of London.

Brewsterite. Crystals monoclinic, with a perfect pearly cleavage like heulandite; but $M \wedge T = 93° 40'$; H. = 4½–5; G. = 2·45; formula analogous to that of heulandite, but baryta and strontia take the place of the lime and soda. Strontian, Argyleshire; Antrim; Mont Blanc; near Barèges, Pyrenees.

Epistilbite. Composition like that of heulandite, but occurs in short and very obtuse monoclinic rhombic prisms ($I \wedge I = 135° 10'$). Skye; the Farôe Ids.; Iceland; Poonah, India; Margaretville, Nova Scotia. *Parastilbite* and *Reissite* are referred here.

Mordenite. Fibrous silky concretions. Morden, Nova Scotia. *Steeleite* is partially altered mordenite.

III. MARGAROPHYLLITE SECTION.

Talc.

Orthorhombic; $I \wedge I = 120°$. In right rhombic or hexagonal prisms. Usually in pearly foliated masses, separating easily into thin translucent pearly folia. Sometimes stellate, or divergent, consisting of radiating laminæ. Often massive, consisting of minute pearly scales; also crystalline granular; also cryptocrystalline.

Lustre eminently pearly, and feel greasy. Color some shade of light green or greenish white; occasionally silvery or pearl white; also grayish green and dark olive-green. H. = 1–1·5; easily impressed with the nail. G. = 2·5–2·8. Laminæ flexible, but not elastic.

VARIETIES. *Foliated Talc.* White to greenish white.

Soapstone or *Steatite.* White, gray, grayish green; either massive, crystalline granular, or impalpable; greasy to the touch. *French chalk* is a milk-white variety, with a pearly lustre. *Potstone* or *Lapis Ollaris* is impure soapstone of grayish green and dark green colors.

Indurated Talc. A slaty talc, of compact texture, and above the usual hardness, owing to impurities.

Rensselaerite. A compact cryptocrystalline rock, from St. Lawrence and Jefferson cos., N. Y., white, yellow, grayish white, to brown and black. Has sometimes the form and cleavage of pyroxene, and is in part at least a prod-

uct of the alteration of that mineral. Part of *Pyrallolite* belongs here.

Composition. $\frac{1}{5}H_2\frac{4}{5}MgO_2Si$ = Silica 62·8, magnesia 33·5, water 3·7 = 100. Usually contains a little iron replacing magnesium. B.B. infusible; after moistening with cobalt nitrate a pink tint; in closed tube gives a little water, but not till highly heated. Not acted upon by hydrochloric acid.

Diff. The extreme softness, greasy feel, foliated structure, when crystallized, and pearly lustre of talc are good characteristics. Differs from mica also in being inelastic, although flexible; from chlorite, kaolinite, and serpentine in yielding little water when heated in a glass tube. Only the massive varieties resemble the last-mentioned species, and chlorite has a dark olive-green color. Pyrophyllite, which cannot be distinguished, in some of its varieties, by the eye alone, from talc, becomes dark blue when moistened with cobalt nitrate and ignited.

Obs. Occurs in Cornwall, near Lizard Point; at Portsoy in Scotland; at Croky Head, Ireland; in the Greiner Mountain, Saltzburg. Handsome foliated talc occurs at Bridgewater, Vt.; Smithfield, R. I.; Dexter, Me.; Lockwood, Newton, and Sparta, N. J., and Amity, N. Y.; Staten Island, near the Quarantine, both the common and indurated; at Cooptown, Md., green, blue, and rose-colored; in Georgia. *Steatite* or soapstone is abundant, and is quarried at Grafton, Cambridgeport, Chester, Perkinsville, Saxton's River, Vt.; at Francestown, Orford, Weare, Warner, Richmond, Haverhill, N. H.; at Middlefield, Mass.; in Loudon Co., Va., and at many other places.

Talc is ground up and used largely for adulterating soap, and to some extent in the manufacture of paper.

Soapstone is sawn into slabs and used for linings of furnaces, stoves and fire-places, etc.; made into images in China, and into inkstands and other forms in other countries; ground up for use in lubricating machinery, and the inside of a tight boot; worked into vessels for culinary purposes in Lombardy. Soapstone is also used in the manufacture of porcelain; it makes the biscuit semi-transparent, but brittle and apt to break with slight changes of heat. It forms a polishing material for serpentine, alabaster, and glass.

Pyrophyllite.—Agalmatolite, in part.

Near talc in crystallization, cleavage, its occurrence in both thin foliated and fine-grained massive forms, its greasy feel, its white to pale green colors, varying to yellowish, its feeble degree of hardness (1–2). The folia are sometimes radiated. G. = 2·75–2·92.

Composition. An *aluminous* bisilicate, instead of a magnesian, mostly of the formula, AlO_9Si_3. The Chesterfield, S. C., mineral afforded Genth, Silica 64·82, alumina 24·48, iron sesquioxide 0·96, magnesia 0·33, lime 0·55, water 5·25 = 100·39. B.B. whitens and fuses with difficulty on the edges; a deep blue color with cobalt solution; yields water in the closed tube. Radiated varieties exfoliate in fan-like forms.

Obs. Compact pyrophyllite is the chief constituent of a kind of slate or schist, which has been used for slate pencils, and hence is called *pencil-stone.* Occurs in the Urals; at Westana in Sweden; in Elfdalen, with cyanite; foliated, in N. Carolina, in Cottonstone Mountain; Chesterfield District, S. C., with lazulite and cyanite; Lincoln Co., Ga., on Graves Mountain; near Little Rock, Ark.; compact slaty in the Deep River region, N. C., and at Carbonton, Moore County, N. C.

Sepiolite.—Meerschaum of the Germans.

Usually compact, of a fine earthy texture, with a smooth feel, and white or whitish color; also fibrous, white to bluish green in color. H. = 2–2·5. The earthy variety floats on water.

Composition. $\frac{1}{3}H_2\frac{2}{3}MgO_3Si + 1\frac{1}{2}$ aq = Silica 60·8, magnesia 27·1, water 12·1 = 100. B.B. infusible, or fuses with great difficulty on the thin edges. Much water in a closed tube. A pink color with cobalt solution.

Occurs in Asia Minor in masses in stratified earthy deposits, and extensively used for pipe-bowls; also found in Greece, Moravia, Spain, etc.; also in fibrous seams at a silver mine in Utah.

Aphrodite. Similar to the preceding. $MgO_3Si + \frac{2}{3}H$. From Sweden.

Cimolite. A clay from the Island of Argentiera, Kimole of the Greeks; Richmond, N. S. W.

Smectite. A kind of "Fuller's Earth," a name given to unctuous clays used in fulling cloth.

Montmorillonite. Rose-red to white, bluish; soft and tender; a hydrous aluminium silicate. Montmorillon, France; Cornwall; Branchville, Ct. *Stolpenite, Confolensite, Delanouite, Steargillite,* the *Saponite* of Plombières, are related to this species.

Glauconite.—Green Earth.

In dark olive-green to yellowish green grains, or granular masses, with dull lustre. H. = 2. G. = 2·2–2·4.

Composition. Essentially a silicate of iron and potassium. Formula $RRO_{12}Si_4 + 3$ aq, in which R is mainly Fe and K_2, and R is Al, but sometimes largely Fe. Analyses give mostly 50–58 per cent. silica, 20–24 iron protoxide, 4–12 of potash, and 8–12 of water. B.B. fuses easily to a magnetic glass. Yields water in a closed tube.

Obs. Mixed with more or less sand, it forms thick beds called "green sand" in the Cretaceous formation, and also in the Lower Tertiary; also occurs in other older rock formations down to the Lower Silurian. Found also, first by Pourtales, in the pores of corals and cavities of Rhizopod shells over the existing sea-bottom, showing it to be a marine product, and one now in progress of formation. The grains of the Cretaceous, Tertiary, and Lower Silurian beds were shown first by Ehrenberg to be the casts of the interior of shells of Rhizopods. The silica has been supposed to come from the siliceous secretions of a minute sponge growing in the cavities that afterward became occupied by the glauconite. Abundant in New Jersey a few miles north, east and south of Freehold.

Bravaisite. Gray to greenish; H. = 1–2; feel greasy. Near glauconite.

Celadonite. A green earth with 53 per cent. of silica, from amygdaloid, near Verona; Scotland. Probably an impure chlorite.

Chloropal. Massive; somewhat opal-like in appearance; greenish yellow to pistachio-green; consists chiefly of silica, iron sesquioxide, and water. *Nontronite, Pinguite, Unghwarite,* and *Gramenite* are varieties of it. Unghwar, Hungary; Nontron, France; near Göttingen; Bohemia; Mudgee, N. S. W.

Stilpnomelane. Foliated and also fibrous, or as a velvety coating; black to brownish and yellowish bronze in color and lustre; G. = 3–3·4; chiefly silica and iron oxides, with 8 to 9 per cent. of water. *Chalcodite,* in velvety coatings at the Sterling Iron Mine, Antwerp, Jefferson Co., N. Y., is here included.

Serpentine.

Usually massive and compact in texture; also lamellar or foliated, the folia brittle; also columnar, asbestiform, and

delicately silky fibrous. Often in crystals pseudomorphous after chrysolite and some other species. Color light to dark oil-green, to olive-green and blackish green; also greenish yellow, brownish yellow, brownish red; rarely white. Lustre weak; resinous, inclining to greasy. Translucent to nearly opaque. H. = 2·5–4. G. = 2·5–2·6. Feel, especially of powder, a little greasy. Tough. Fracture conchoidal.

Composition. A hydrous magnesium silicate, like talc, but containing more water and less silica. $H_2Mg_3O_8Si_2 + 1\,aq$ = Silica 43·48, magnesia. 43·48, water 13·04 = 100. B.B. fuses with much difficulty on thin edges. Yields water in the closed tube. Decomposed by hydrochloric acid, leaving a residue of silica. In some kinds iron replaces part of the magnesium.

Specimens of a rich oil-green color, and translucent, are called *precious serpentine,* and the nearly opaque kinds *common* serpentine. *Chrysotile* is fibrous serpentine; it includes *Amianthus* and part of *Asbestus.* Unlike true asbestus, it affords much water in a closed tube. *Metaxite, Picrolite,* and *Baltimorite* are coarse fibrous kinds. A thin foliated variety, from Hoboken, N. J., was named *Marmolite,* before it was known to be serpentine; *Antigorite* and *Williamsite* are coarse foliated varieties; *Refdanskite* contains nickel. A porcelain-like serpentine—the Meerschaum of Taberg and Sala—has been called *Porcellophite;* and a resin-like variety, *Retinalite* and *Vorhauserite.* Mixed with limestone it makes a green clouded marble called *Verd-antique* and *Ophiolite.*

Diff. The distinguishing characters of the compact mineral are no cleavage, feeble lustre, slightly waxy or oily lustre, little hardness, being so soft as to be easily cut with a knife, yielding much water, and specific gravity not over 2·65.

Obs. Named from its green color, which is often clouded, serpent-like. Common as a rock as well as an imbedded mineral. It has been made through the alteration of anhydrous magnesian silicates, as chrysolite, pyroxene, enstatite, hypersthene, tremolite, actinolite, chlorite, chondrodite, and others. Chrysolite is the most common source. Some basaltic and other eruptive rocks consisting largely of pyroxene and chrysolite have been changed to impure serpentine. Foliated chlorite has given origin to some foliated

serpentine, as probably that of marmolite; and cleavable pyroxene to the partially altered foliated kinds called *Bastite*, *Schiller-spar*, and *Antillite*. *Pelhamite* is an asbestiform serpentine material made by alteration. The white marble of Essex Co., N. Y., dotted with green serpentine, a "verd-antique," was once dotted probably with pyroxene; and other verd-antiques have had a similar origin. The serpentine of New Rochelle, N. Y., was made in part from enstatite and tremolite or actinolite; and that of Brewster, N. Y., part of which is white, from chondrodite, chlorite, enstatite, and to a small extent from biotite and dolomite. The "Eozoön," consisting of delicate layers of serpentine and calcite, is regarded by some as serpentine of mineral origin, which became cracked from drying while it was in a semi-gelatinous state, and which then had the delicate cracks filled by calcite.

Serpentine occurs in Cornwall; near Portsoy in Aberdeenshire; in Corsica, Siberia, Saxony, Norway, Silesia, etc.

In the United States it occurs at Phillipstown, Port Henry, Gouverneur, Warwick, New Rochelle, Rye, Staten Island, N. Y.; Newburyport, Westfield, Blandford, Mass.; Kellyvale, New Fane, Vt.; Deer Isle, Me.; New Haven, Ct.; Bare Hills, Md.; Hoboken, N. J.; Brewster's, Putnam Co., N. Y.; Texas and elsewhere, Pa.; in N. Carolina; over large areas N. and S. of San Francisco, Cal.; Canada, at Orford, Ham, Bolton, etc.

Serpentine when polished has much beauty, especially when constituting a *verd-antique* marble. Chromic iron or magnetite is usually disseminated through it, and increases the variety of its colors. It occurs near Milford and New Haven, Ct.; Port Henry, Essex Co., N. Y., and elsewhere. Pennsylvania serpentine is used as a building-stone in Philadelphia.

The asbestus of this species is used like hornblende asbestus, and largely obtained for the trade at Staten Island, in Canada, and in Italy. But it is an inferior kind, owing to the 14 pounds of water present to every hundred of the pure material, which a high heat will drive off and, if it is confined, may do it explosively.

Bowenite. Has the composition of serpentine, but the hardness 5·5–6, and the aspect of nephrite, with G. = 2·59–2·8. Smithfield, R. I.

Deweylite.

Massive. Color whitish, yellowish, brownish yellow, greenish, reddish. Has the aspect of gum-arabic or a resin. Very brittle. H. = 2–3·5. G. = 1·9–2·25.

Composition. Near serpentine, but containing 20 per cent. of water.

Obs. From Middlefield, Mass.; Bare Hills, Md. (*Gymnite*); Texas, Pa.; the Fleims Valley, Tyrol.

Cerolite. Related to deweylite; from Silesia. *Limbachite* from Limbach, and *Zöblitzite* from Zöblitz, are similar.

Hydrophite. Like deweylite, but containing iron in place of part of the magnesium. Taberg in Smaoland.

Jenkinsite is a fibrous variety of hydrophite occurring on magnetite at O'Neil's mine, in Orange Co., N. Y.

Genthite or *Nickel-gymnite.* Similar to deweylite, but containing much nickel; analysis affording Silica 35·36, nickel protoxide 30·64, iron protoxide 0·24, magnesia 14·60, lime 0 26, water 19·09 = 100·19; G. = 2·4. Texas, Pa.; Webster, N. C.; Michipicoten Island, Lake Superior; Malaga, Spain; Saasthal, Upper Valois. *Röttisite* is similar.

Saponite.

Soft, clay-like, of the consistence, before drying, of cheese or butter, but brittle when dry. Color white, yellowish, grayish green, bluish, reddish. Does not adhere to the tongue.

Composition. A hydrous silicate of magnesia containing some alumina.

From Lizard's Point, Cornwall, in serpentine. Also from geodes of datolite, Roaring Brook, Ct.; in trap, north shore of Lake Superior.

Kaolinite.

Orthorhombic; $I \wedge I = 120°$. Massive, clay-like, but consisting often of thin, microscopic, rhombic or hexagonal crystals; either compact, friable, or mealy. Feels greasy. Color white, grayish white, yellowish, sometimes brownish, bluish, or reddish. Scales flexible, inelastic. H. = 1–2·5. G. = 2·4–2·6.

Composition. $H_2AlO_8Si_2 + 1\,aq$ = Silica 46·4, alumina 39·7, water 13·9 = 100. The similarity of the composition to that of serpentine will be seen on comparing the two formulas. B.B. infusible. A blue color with cobalt solution. Yields water in the closed tube. Insoluble in acids.

Obs. The soapy feel of kaolinite distinguishes a clay consisting of it or containing much of it; when common clays are "unctuous" it is usually owing to the presence of kaolinite. Kaolinite has been made through the decomposition of aluminous minerals, and especially feldspars, but mostly from the potash feldspar, orthoclase. In the case of these feldspars the process (1) removes the alkalies; (2) leaves the alumina, or a large part of it, and part of the silica; and (3) adds water. So that orthoclase, $K_2AlO_{1.5}Si_6$ loses K_2 and part of the Si and O, and becomes changed to $H_2AlO_3Si_2 + 1$ aq; half the water which is added replaces K_2 which is removed. Many granites, gneisses, and feldspar-bearing quartzytes undergo rapidly this change, so that extensive beds of kaolinite have been formed and are now making in many regions. This result is promoted by the action of the carbonic acid of rain and other waters, which removes the alkali; also by that of the organic acids which the decomposition of plants or animals contribute to such waters. The kaolinite is usually washed out by flowing waters from the decomposed material to make the large pure deposits. The New Jersey clay-beds of the Cretaceous formation and those of Long Island, N. Y., are mainly kaolinite. A pure kaolinite bed occurs at Brandon, Vt., along with a limonite bed; a much larger at Clayton in New Marlboro', Mass.; also in Delaware and Chester cos., Pa.; at King's Mtn., S. C.; also in other States. Most of the limonite beds of Eastern N. America afford some kaolinite; yet it is generally more or less colored by iron oxide.

Common clays consist of powdered feldspar, quartz, and other mineral material, with more or less kaolinite. They burn red in case they contain iron in the state ordinarily present in them of iron carbonate, or hydrous iron oxide (limonite), or in combination with an organic acid, or in some other alterable state of composition, heat driving off the carbonic acid or water, or destroying the organic acid, and so leaving the red oxide of iron (or sesquioxide), or favoring its production. But the iron may be so combined as not to give the red color; and this has been found to be true with the clays from which the cream-colored Milwaukee (Wisconsin) brick are made, and that of other clay beds in that vicinity. The iron may be there in the state of the silicate, zoisite; or it may form this mineral, or one allied to it, in the kiln. When clay consists in part of

powdered feldspar, it is more or less fusible and unfit for making fire-bricks.

Pure kaolinite (or *kaolin* as it is ordinarily called) is used in making the finest porcelain. For this purpose it is mixed with pulverized feldspar and quartz, in the proportion needed to give, on baking, that slight incipient degree of fusion which renders porcelain translucent. The name kaolin is a corruption of the Chinese word *Kauling*, meaning *high ridge*, the name of a hill near Jauchau-Fu, where the mineral is obtained; and the *petuntze* (peh-tun-tsz) of the Chinese, with which the kaolin is mixed in China for the manufacture of porcelain, is, according to S. W. Williams, a quartzose feldspathic rock, consisting largely of quartz. The word porcelain was first given to China-ware by the Portuguese, from its resemblance to certain seashells called *Porcellana;* they supposed it to be made from shells, fish-glue, and fish-scales (S. W. Williams).

The white clays are used for stoneware. fire-bricks, retorts for gas-works, sewer-pipes, etc.; and the pure kaolin extensively for giving body and weight to paper.

Pinite.

Amorphous, and usually cryptocrystalline; but often having the form of the crystals of other minerals from the alteration of which it has been made. Colors grayish, greenish, brownish, and sometimes reddish. Lustre feeble; waxy. Translucent to opaque. H. = 2·5–3·5. G. = 2·6–2·7; some, 2·85.

Composition. Mostly $(H_3K)_2Al_2O_{20}Si_5$. The pinite of Saxony afforded Silica 46·83, alumina 27·65, iron sesquioxide 8·71, magnesia 1·02, lime 0·49, soda 0·40, potash 6·52, water 3·83 = 99·42; and, in another analysis, potash 10·74. It has in part the physical characters of serpentine; but, at the same time, it has nearly the composition of a hydrous potash mica. Some of it has been proved to consist of very minute scales that are mica, and it is inferred that pinite may usually be a massive form of hydrous muscovite.

Obs. The varieties are in general pseudomorphs after different minerals, and hence comes a part of their variations in composition. They include *Pinite,* from the Pini Mine, near Schneeberg and elsewhere; *Gieseckite,* pseudomorph after nephelite from Greenland, and from

Diana, N. Y.; *Killinite*, formed from spodumene, at Killiney Bay, Ireland, Branchville, Ct., and Chesterfield, Mass.; *Dysyntribite*, from Diana, N. Y., identical with gieseckite; *Pinitoid*, from Saxony; *Wilsonite*, from Bathurst, Canada, having the cleavage of scapolite; *Terenite*, from Antwerp, N. Y., like Wilsonite; *Agalmatolite*, or *Pagodite*, from China, being one of the materials for carving into images, ornaments, models of pagodas, etc.; *Gigantolite* and *Iberite*, which have the form of iolite. A variety from Elba was formed from andalusite.

Polyargite, Rosite, Cataspilite, Biharite, Gümbelite, Rauite, Restormelite, are related materials.

Pholerite, Halloysite, Severite, Glagerite, Lenzinite, Bole, Lithomarge, are names of clay-like minerals.

Palagonite. The material of some tufas, and the result of change through the agency of steam or hot water at the time, probably, of the deposition of the material; a mixture, and not a true mineral. Tufas of Iceland, Sicily, etc. Named from Palagonia, Sicily.

HYDROMICA GROUP.

The following species are mica-like in cleavage and aspect, but talc-like in wanting elasticity, in greasy feel, and in pearly lustre. They are sometimes brittle. Common mica, muscovite, readily becomes hydrated on exposure; but hydrous micas are not all a result of alteration. Hydromica schists form extensive rock-formations, equal to those of the ordinary mica schists. They were for the most part called *Talcose slate* (or *Talk-schiefer* in German) from their greasy feel, until the fact was ascertained that they contained no magnesia: a point demonstrated for the Taconic slates of the western border of Massachusetts, by C. Dewey, in 1819, and later, by G. F. Barker, for those of Vermont.

Margarodite. Damourite. Hydrous micas related to muscovite, which see (p. 288). *Parophite* is a hydromica schist from Pownal, Vt., and Stanstead, Canada. *Sericite* and *sericite schist* are hydromica schist from near Wiesbaden and elsewhere.

Groppite. A rose-red to brownish red foliated mineral from Gropptorp, Sweden.

Euphyllite. Mica-like; folia rather brittle; lustre pearly, white or colorless; contains much sodium; an analysis afforded Silica 41·6, alumina 42·3, lime 1·5, potash 3·2, soda 5·9, water 5·5 = 100. Occurs with corundum at Unionville, Delaware County, Pa.

Cookeite. In minute mica-like scales, and in slender six-sided prisms; affords only 2·57 of potash, with 2·82 of lithia; the water

13·41 per cent. On crystals of red tourmaline, at Hebron and Paris, Me., having been formed through their alteration. Named after Prof. J. P. Cooke, of Cambridge, Mass.

Voigtite. The mica of a granite at Ehrenberg, near Ilmenau, which has the composition of biotite, plus 9 per cent. of water.

Roscoelite. A vanadium-mica of dark brownish green color, occurring in micaceous scales, and affording over 20 per cent. of vanadium oxides, along with 47·69 of silica, 14·10 of alumina, 7·59 of potash, 4·96 of water, and a little magnesia and soda. Probably a mixture. From Granite Creek Gold Mine, El Dorado County, California.

Fahlunite.

In six and twelve-sided prisms, usually foliated parallel to the base, but owing the prismatic form to the mineral from which it was derived. Folia soft and brittle, of a grayish green to dark olive-green color, and pearly lustre. G. = 2·7.

Composition. A hydrous silicate of aluminium and iron with little or no alkali, and in this last point differing from pinite. An average specimen afforded Silica 44·60, alumina 30·10, iron protoxide 3·86, manganese protoxide 2·24, magnesia 6·75, lime 1·35, potash 1·98, water 9·35 = 100·23. B.B. fuses to a white glass. In a closed tube gives water. Insoluble in acids.

Diff. It is distinguished from talc by affording much water before the blowpipe, and readily by its association with iolite, and its large hexagonal forms, with brittle folia.

Obs. Fahlunite has been derived from the alteration of iolite. The quantivalent ratio of iolite for the protoxides, sesquioxides, and silica is 1 : 3 : 5 ; and for fahlunite, the same, with 1 for the water, making the whole 1 : 3 : 5 : 1. The hydration appears to go on at the ordinary temperature, and in some localities all the iolite to a considerable depth in the rock is changed to fahlunite. There are different varieties, depending on the amount of water, and the conditions under which the change has taken place. The names they have received are *Hydrous Iolite, Chlorophyllite, Esmarkite, Aspasiolite, Pyrargillite, Triclasite. Fahlunite* was so named from its locality, Fahlun, Sweden; and *Chlorophyllite* from its greenish color and foliated structure, the specimens to which it was given occurring at Unity, N. H. Haddam, Ct., is another locality. *Gigantolite* and *Iberite* are also altered iolite, but they contain potash, and belong hence to the Pinite Group.

Venasquite. Resembles ottrelite; lamellar; grayish black. In analysis, Silica 44·79, alumina 29·71, iron protoxide 20·75, magnesia 0·62, water 4·93 = 100·80; oxygen ratio 1 : 3 : 6 : 10. From Vénasque, Pyrenees.

Ærinite. A bright blue earthy mixture. From the Pyrenees.

CHLORITE GROUP.

The chlorite group includes the hydrous *Subsilicates* of the Margarophyllite Section and also some related species that are *Unisilicates*. The proportion of silica is small, the percentage afforded by analyses being under 38, and mostly under 30. The minerals when well crystallized are foliated like the micas, and have the plane angle of the base of the crystals 120°, but the folia are inelastic and in some species brittle. They also occur in fibrous and in fine granular and compact forms, and the latter are usually most common. Green, varying from light to blackish green, is the prevailing color, yet gray, yellowish, reddish, and even white and black also occur; and the colored transparent or translucent are dichroic. The green color is owing to the presence of iron, and fails only in species containing little or none of it. All of the species yield water in a closed tube. The quantivalent (or combining) ratio for R + R and Si is, in the

Pyrosclerite subdivision.....1 : 1.
Chlorite subdivision.....1 : $\frac{4}{5}$, 1 : $\frac{8}{9}$, 1 : $\frac{1}{2}$.
Chloritoid subdivision.....1 : $\frac{1}{2}$ to 1 : $\frac{1}{3}$.

The chlorite subdivision includes Penninite, Ripidolite, and Prochlorite, together with some related dark green to blackish green species. Some species of this subdivision characterize extensive rock-formations, making chlorite schist or slate; and they give rise also to chloritic varieties of other rocks. Moreover, chlorite is a result of the alteration of pyroxene, hornblende, and some other iron-bearing minerals; and pyroxenic igneous rocks, like basalt, are often strongly chloritic (as revealed by the microscopic examination of thin transparent slices), in consequence of this alteration—but alteration that took place before the rock had cooled. Such green chloritic material, where the species is not determinable, has been called *Viridite*. The cavities in amygdaloid are often lined, and sometimes filled, by a species of chlorite, which was made from certain con-

stituents of the amygdaloid in the manner just stated; and the rocks adjoining trap-dikes are at times penetrated by chlorite made in them by means of the heat, and the moisture contained in them or ascending with the erupted rock.

Hisingerite.

Massive; reniform. Color black to brownish black. Streak yellowish brown. Lustre greasy, inclining to vitreous. H. = 3. G. = 3·045.

Composition. A hydrous iron silicate, $(H_2\frac{2}{3}Fe)_2O_{12}Si_3 + 4\,aq$ = Silica 35·9, iron sesquioxide 42·6, water 21·5 = 100. In some analyses part of the iron is in the protoxide state. B.B. fuses with difficulty to a magnetic slag.

Obs. From Sweden; Norway; Finland. *Scotiolite* and *Degeröite* are referred here. *Melanolite*, from Milk-Row quarry, near Charlestown, Mass., is related in composition, if the material analyzed was a pure species.

Gillingite, from Sweden (including *Thraulite* from Bavaria), *Lillite*. Other hydrous silicates of iron.

Ekmannite. Foliated, chlorite-like; a hydrous iron silicate, but the iron mostly in the protoxide state. Sweden in the rifts of magnetite.

Epichlorite. Between chlorite and schiller spar; a hydrous silicate of aluminium, iron, and magnesium. Altered bronzite? In serpentine at Harzburg.

Neotocite (*Stratopeite*) and *Wittingite* are results of the alteration of rhodonite, and contain manganese. *Stübelite* also contains manganese oxide.

Strigovite from Striegau, *Jollyte* from Bodenmais, *Hullite* from Ireland, are hydrous silicates of aluminium and iron, with little magnesium.

Pyrosclerite.

Orthorhombic or monoclinic. Mica-like in cleavage; folia flexible, not elastic. Color apple-green to emerald-green. Lustre pearly. H. = 3. G. = 2·74.

Composition. $(\frac{2}{3}Mg_3\frac{1}{3}Al)_2O_{12}Si_3 + 3\,aq$ = Silica 38·9, alumina 14·8, magnesia 34·6, water 11·7 = 100. B.B. fuses to a grayish glass; gelatinizes with hydrochloric acid.

Obs. Occurs in serpentine, on Elba.

Chonicrite (*Metaxoite*). Related to the above in composition, but affords 12 to 18 per cent. of lime.

Vermiculite.

Mica-like in cleavage. In aggregated scales. Also in large micaceous crystals or plates. Laminæ flexible, not

elastic. Color gray, brown, yellowish brown. Lustre pearly.

Composition. Mg_3 (Fe, Al) $O_{12}Si_3$. Exfoliates when heated, and when scaly-granular the scales open out into worm-like forms; and thence the name, from the Latin *vermiculor*, to breed worms; B.B. fuses finally to a gray mass. From Milbury, Mass.

Jefferisite is a similar mineral in composition and exfoliation, occurring in broad folia; composition $\frac{6}{8}Mg_3\frac{1}{8}(Fe, Al)O_{12}Si_3$. In serpentine in Westchester, Pa. *Culsageeite* from Culsagee, North Carolina; *Hallite* from Lerni, Delaware Co., Pa; *Protovermiculite* from Magnet Cove, Ark.; *Philadelphite*, from Philadelphia, Pa., are other micaceous hydrous unisilicates, similar to vermiculite and jefferisite in exfoliation. *Kerrite* and *Maconite* are related to the above; they are from Franklin, Macon Co., North Carolina. The quality of exfoliating is due to the water present, and is produced in some mica by alteration. It is a question how far these vermiculite-like species are alteration products.

Penninite.—Chlorite in part. Pennine.

Rhombohedral. Cleavage basal and highly perfect, mica-like. Also massive, consisting of an aggregation of scales, and cryptocrystalline. Color green of various shades; also yellowish to silver-white, and rose-red to violet. Lustre pearly on cleavage surface. Transparent to translucent. Laminæ flexible, not elastic. H. = 2–2·5, 3 on edges. G. = 2·6–2·75.

Composition. A specimen from Zermatt, in the Pennine Alps, afforded Silica 33·64, alumina 10·64, iron sesquioxide 8·83, magnesia 34·95, water 12·40 = 100·46. The rose-red, from Texas, Pa., gave Silica 33·20, alumina 11·11, chromium oxide 6·85, iron sesquioxide 1·43, magnesia 35·54, water 12·95, lithia and soda 0·28, potash 0·10 = 101·46. Other Texas specimens afforded 0·90 to 4·78 per cent. of chromium oxide. B.B. exfoliates somewhat and fuses with difficulty. Partially decomposed by hydrochloric acid, and wholly so by sulphuric acid.

From Zermatt, Ala in Piedmont, the Tyrol, etc. *Kämmererite*, *Rhodochrome*, and *Rhodophyllite* include the reddish variety from near Miask, Russia; Texas, Pa.; etc. Pseudomorphs after hornblende, named *Loganite*, have the composition of this species; and so has the massive mineral called *Pseudophite* and *Allophite*.

Delessite. A fibrous chlorite like mineral near the above in composition. From amygdaloid at Oberstein.

Euralite. An amorphous chlorite, near Penninite. From Eura, Finland; in amygdaloid.

Diabantite (*Diabantochronyn*). A chlorite from amygdaloid. A Farmington (Conn.) specimen afforded Hawes, Silica 33·68, alumina 10·84, iron sesquioxide 2·86, iron protoxide 24·33, MnO and CaO 1·11, magnesia 16·52, soda 0·33, water 10 02 = 99·69. *Steatargillite* contains much iron.

Chlorophæite. A doubtful chlorite. Amygdaloid, in Scotland.

Ripidolite.—Chlorite, in part.

Monoclinic. Similar in cleavage and mica-like character to penninite, and also in its colors, lustre, hardness, and specific gravity.

Composition. A specimen from Chester Co., Pennsylvania, afforded Silica 31·34, alumina 17·47, chromium sesquioxide 1·69, iron sesquioxide 3·85, magnesia 33·44, water 12·60 = 100·39. B.B. and with acids nearly like penninite. A variety from Willimantic, Ct., exfoliates like vermiculite and jefferisite.

Kotschubeite is a red variety from the Urals. *Clinochlore* and *Grastite* are here included. Occurs at Achmatovsk and elsewhere in the Urals; at Ala, Piedmont; at Zermatt; Westchester, Unionville and Texas, Pa.; Brewster's, N. Y.

Prochlorite.—Chlorite in part.

Hexagonal. Similar in cleavage and mica-like characters to the preceding. Color green to blackish green; sometimes red across the axis by transmitted light. G. = 2·75–3. Laminæ not elastic.

Composition. A specimen from St. Gothard afforded Silica 25·36, alumina 18·56, iron protoxide 28·79, magnesia 17·09, water 8·96 = 98·70; and a North Carolina specimen, Silica 24·90, alumina 21·77, iron sesquioxide 4·60, iron protoxide 24·21, manganese protoxide 1·15, magnesia 12·78, water 10·59 = 100. B.B. same as for preceding.

Lophoite, Ogcoite, Helminthe belong here. Occurs at St. Gothard; Greiner in the Tyrol; Traversella in Piedmont, and many other places in Europe. Also at Steele's Mine, N. C.

Leuchtenbergite. A prochlorite with the base almost solely magnesium. *Rubislite* is a doubtful chlorite.

Aphrosiderite. Near prochlorite in composition. Weilburg, Germany.

Venerite. A pale green earthy chlorite-like material containing copper. Berks Co., Pa.

Corundophilite. Near prochlorite. With corundum at Asheville, N. C.; Chester, Mass. *Amesite.*

Grochauite. From Grochau in Silesia.

Cronstedtite. Hexagonal, with perfect basal cleavage; black; G. = 3·35; consists mainly of silica, iron oxides, and water, with a little manganese oxide. Bohemia; Cornwall.

Thuringite. Another hydrous iron silicate; G. = 3·15-3·20; dark green to yellow-green. Thuringia; Hot Springs, Arkansas; near Harper's Ferry, on the Potomac; Unionville, Pa. (*Pattersonite*).

Margarite.—Emerylite. Diphanite. Clingmanite. Corundellite.

Orthorhombic. Foliated, mica-like. Laminæ rather brittle. Color white, grayish, reddish. Lustre of cleavage surface strong pearly and brilliant, of sides of crystals vitreous. H. = 3·5–4·5. G. = 2·99.

Composition. $H_2RAl_2O_{12}Si_2$ = Silica 30·1, alumina 51·2, lime 11·6, soda 2·6, water 4·5 = 100. B.B. whitens and fuses on the edges.

Obs. Often associated with corundum and diaspore. Occurs in Asia Minor; at Sterzing in the Tyrol; in the Urals; in Village Green and Unionville, Pa.; Buncombe County, N. C.; Chester, Mass. Named from the Greek *margarites*, a pearl.

Willcoxite. Near margarite.
Dudleyite. An alteration product of margarite.

Chloritoid.—Masonite. Phyllite. Ottrelite.

Monoclinic. Cleavage basal, perfect. Also coarse foliated massive; and in thin disseminated scales (*phyllite* or *ottrelite*). Brittle.

Color dark gray, greenish, to black. Lustre of cleavage surface somewhat pearly. H. = 5·5–6. G. = 3·5–3·6.

Composition. $FeAlO_3Si + 1$ aq = Silica 24·0, alumina 40·5, iron protoxide 28·4, water 7·1 = 100. B.B. becomes darker and magnetic, but fuses with difficulty. Decomposed completely by sulphuric acid.

Obs. Found at Kossoibrod, Urals, with cyanite; in Asia Minor, with emery; at St. Marcel (*Sismondine*); Ottrez, France (*Ottrelite*); Chester, Mass.; in Rhode Island (*Ma-*

sonite); at Brome and Leeds, Canada; in scales (*Phyllite*) characterizing the "spangled mica slate" of Newport, R. I., and Sterling, Goshen, etc., Mass.

Seybertite (*Clintonite*). Monoclinic. Thin foliated; somewhat mica-like; basal cleavage perfect; laminæ brittle; color reddish or yellowish brown to copper-red; lustre pearly submetallic. H. = 4·5. G. = 3. Analysis by Brush obtained Silica 20·24, alumina 39·13, iron sesquioxide 3·27, magnesia 20·84, lime 13·69, water 1·04, potash and soda 1·43, zirconia 0·75 = 100·39, giving the quantivalent ratio for protoxides, sesquioxides, silica, and water 6 : 9 : 5 : ½. Amity, N. Y.; Slatoust, Urals (*Xanthophyllite*, *Waluewite*); Fassa Valley (*Brandisite* and *Disterrite*).

3. HYDROCARBON COMPOUNDS.

The following are the subdivisions here used:

I. Simple Hydrocarbons: Marsh-gas, Mineral oils, and Mineral wax.

II. Oxygenated Hydrocarbons: mostly resins.

III. Asphaltum and Mineral Coals.

I. SIMPLE HYDROCARBONS.

Marsh-Gas.—Light Carburetted Hydrogen. Rock Gas. Natural Gas.

Colorless and inodorous when pure, burning with a yellow flame, and consisting of Carbon 75, hydrogen 25 = 100 = CH_4.

Natural gas varies in composition according to its source, the marsh-gas being mixed with more or less of nitrogen, carbonic acid (CO_2), and some other ingredients. That which occurs bubbling up in marshes, as a result of the decomposition of organic matters and accompanying deoxidation of the atmosphere, often contains much nitrogen; Websky finding the composition in one case: Marsh-gas 43·36, nitrogen 53·67, CO_2 2·97 = 100. The CO_2 is in small amount, although an abundant product of decomposition, because it enters into combinations with earthy bases present, and is to some extent soluble in water.

The natural gas from deeper sources, arising occasionally through springs, and obtained by borings, such as is now used extensively for lighting and heating, is chiefly pure marsh-gas, with often 2 or 3 p. c. of nitrogen, as much

sometimes of carbonic acid, a little free hydrogen, and occasionally very sparingly other gaseous products of the marsh-gas series. The gas of a well of Butler Co., Pa., afforded marsh-gas 80·11, hydrogen 13·50, carbonic acid 0·66, ethane 5·72 = 99·99; and that of the Karg well, Findlay, Ohio, marsh-gas 92·61, hydrogen 2·18, olefiant gas 0·30, nitrogen 3·61, oxygen 0·34, CO_2 0·50, CO 0·26, sulphuretted hydrogen 0·20; but the nitrogen is sometimes in large proportions, up to 25 or 30 per cent. Moreover, the same gas-well gives a varying gas, one in western Pennsylvania affording marsh-gas 57·85 per cent., hydrogen 9·64, nitrogen 23·41 on the 18th of October, 1884; the corresponding numbers 75·16, 14·45, 2·89 on the 25th; and 72·18, 20·02, 0·00, on the 28th.

The districts affording natural gas are usually those affording also more or less mineral oil, the gas and oil being related carbohydrogen compounds, and the latter yielding the former. The strata below are but slightly disturbed, that is, have very gentle pitch if any, and are uncrystalline. Deep below the surface there are blackish carbonaceous shales, slates or limestones, or other deposits of the kinds that yield mineral oil and gas when heated. The gas, like the mineral oil, is supposed to be usually confined in very porous coarse sandstones, and not in open cavities; these porous strata being situated above the gas-yielding stratum. The gas may have been made through the action of low heat on the blackish carbonaceous rocks (slight disturbances having occasioned the heat required).

Beds of buried vegetation occur in the drift of Ohio and the States west, and have been the source of some marsh-gas, "sufficient for domestic use." But the large discharges of gas in the United States are from older deposits from the Tertiary to the Lower Silurian, and come from borings to depths often of 1000 to 2000 feet or more. The wells of Northwestern Ohio (about Findlay) go down to the Trenton limestone; but most of those of Western Pennsylvania and the regions adjoining stop in the Subcarboniferous or Devonian. Black shales are widely distributed over the globe, and the supply may be long continued, although becoming locally exhausted in a short period.

Natural gas was first used for lighting in Fredonia, Erie Co., N. Y., where it is given out from springs. In 1872

and 1873 the waste gas of the petroleum-wells of Butler and Crawford cos., Pa., began to be used for heating boilers and lighting. In 1882 wells were sunk in Western Pennsylvania to obtain gas, and since then natural gas has become in some localities in different States almost the sole fuel and lighting material for large cities and villages, with all their factories. Even Eastern New York, at Knowersville, has a gas-well; and borings are beginning to be productive in the Western States and Territories. The gas is lit up and put out in an instant, gives a steady heat, needs no attention, makes no ashes, requires no storage of fuel, burns without odor, and yields no sulphur to injure furnaces and products of manufacture, etc.

In the Murraysville district—one of those supplying Pittsburg—the best wells afford 10,000,000 to 33,000,000 of cubic feet of gas per day. The pressure at the source is commonly 200 to 300 pounds to the square inch, but in some cases 500 to 700 pounds. In the shallow wells of other regions (and some deep wells) the pressure is often but 50 pounds or less.

With gas of average composition, 1000 cubic feet have, theoretically, the heating power of about 54·4 pounds of bituminous coal and 58·4 of anthracite (S. A. Ford), so that 41,000 ft. of gas are equivalent to 2240 pounds, or a ton, of coal. "It is safe to adopt a practical equivalence of 30,000 cubic feet of gas to 1 ton of coal" (J. P. Lesley).

The first use of natural gas for lighting and heating was in China. In the province of Sz'chuen are artesian wells 1500 to 3000 feet deep, yielding brines, oil, and abundant gas. The gas is conveyed in bamboos and used for evaporating the brines and lighting. In the petroleum region of Baku, on the Caspian, are "eternal fires" of similar origin. All regions of mineral oil probably have stored gas below.

Petroleum.

Mineral oils, varying in density from 0·60 to 0·85. Soluble in benzine or camphene. They consist chiefly of liquids of the Naphtha and Ethylene series. The composition of the Naphtha or Marsh-gas series is expressed by the general formula, $C_nH_{2n}+2$, of which Marsh-gas is the first or lowest term; and that of the Ethylene series by the formula, C_nH_{2n} = Carbon 85·71, hydrogen 14·29 = 100. The

oils vary greatly in density from the lightest naphtha, too inflammable for use in lighting, to thick viscid fluids; and thence they pass by insensible gradations into asphaltum or solid bitumen. The Marsh-gas series contains also gases, of the composition C_2H_6 and C_3H_8 and these, in addition to Marsh-gas, often exist in connection with petroleum.

Petroleum occurs in rocks of all ages, from the Lower Silurian to the most recent; in limestones, porous or compact sandstones, and shales; but it is mostly obtained from cavities existing among the earth's strata or more probably from the porous strata themselves. Black shales and much bituminous coal afford it abundantly when they are heated; but the oil obtained is not present in these rocks, for when the rocks are treated with benzine, the benzine takes up little or none; instead, the rocks contain an *insoluble* hydrocarbon, which yields the oil when heat is applied.

In the United States the oil, or the hydrocarbon which yields it, has been observed in beds of the Lower and Upper Silurian, Devonian, Carboniferous, Triassic, Cretaceous, and Tertiary eras. Surface oil-springs also occur in many places. Foreign regions noted for mineral oil are Rangoon in Burmah, where there are about 100 wells; at Baku on the Caspian, whose springs promise to supply Russia and Europe with petroleum. Pliny mentions the oil spring of Agrigentum, Sicily, and says that the liquid was collected and used for burning in lamps, as a substitute for oil. Moreover he distinguishes the oil from the lighter and more combustible naphtha, a locality of which about the sources of the Indus, "in Parthia," he mentions.

Petroleum is obtained chiefly at the present time from porous oil "sands" (coarse sandstones), or cavities between or within the rock strata, reached by boring. Being under pressure from the gas associated with it, and also, in many cases, that of water, it rises to the surface in the boring, and sometimes makes a "spouting" well. As early as 1833, Hildreth mentioned the discharge of oil with the waters of the salt wells of the Little Kanawha Valley, and speaks also of a well near Marietta, Ohio, which threw out at one time, he says, 50 to 60 gallons of oil at "each eruption." The great oil-districts of Pennsylvania are the Venango in the western part, and the Bradford in the northern (McKean Co.), which extends 5 m. beyond the New York boundary. Oil is also obtained in Ohio, 25 m. N. of Zanesville, and

in Kentucky and West Virginia, but not abundantly. There are also productive wells in California in the San Fernando district, Los Angeles Co., and in Ventura Co. There are also wells in Colorado and Wyoming.

The mineral oil of the rocks has been formed through the decomposition of animal and vegetable substances. From the nature of the shales which most abound in the species of hydrocarbons that yield oil, it is evident that the rock material of the shales was in the state of a fine mud; that through this mud much vegetable or animal matter was distributed, almost in the condition of an emulsion; that the stratum of mud becoming afterward overlaid by other strata, the decomposition of vegetable or animal matter went forward without the presence of atmospheric air, or with only very little of it. Under such circumstances either vegetable material or animal oils might be converted, as chemists have shown, into mineral oil. Dry wood consists approximately (excluding the ash and nitrogen) of 6 atoms of carbon to 9 of hydrogen, and 4 of oxygen. If now all the oxygen of the wood combines with a part of the carbon to form carbonic acid, and this $2CO_2$, thus made, is removed, there will be left C_4H_3; twice this, C_8H_{18}, is the formula of a compound of the Marsh-gas or Naphtha series. Again animal oils, by decomposition under similar circumstances, produce like results. Removing from oleic acid its oxygen, O_2, and 1 of carbon—the two together equivalent to 1 of carbonic acid—there is left $C_{17}H_{34}$, which is an oil of the Ethylene series. So margaric acid would leave, in the same way, $C_{16}H_{34}$, or a combination of oils of the Marsh-gas or Naphtha series. Warren and Storer have obtained from the destructive distillation of a fish-oil, after its saponification by lime, several compounds of the Marsh-gas series, besides others of the Ethylene and Benzole series. The decompositions in nature may not have been as simple as those in the above illustrations, yet the facts warrant the inference that the oils may have been derived either from vegetable or animal matters. Fossil fishes are often found abundantly in black oil-yielding shales, and Dr. Newberry has suggested that fish-oil may be the most abundant source of the oil and the oil-yielding hydrocarbons.

The oil which is collected in porous sandstones or cavities among the strata, as in Western Pennsylvania, is believed by most writers on the subject to have come from underlying

rocks, such as the black oil-yielding shales. The heat produced in the rocks by the friction attending movements and uplifts is supposed to have been sufficient to have made the oil from the hydrocarbon of the carbonaceous shale or other rock, and to have caused it to ascend among the strata to the cavities or porous "sands" where it was condensed, and now is found by boring.

The oils, exposed to the air and wind, undergo change in three ways. *First:* the lighter naphthas evaporate, leaving the denser oils behind, and, ultimately, the viscid bitumens; or else paraffin, according as paraffin is present or not in the native oil. At the naphtha island of Tschelekan, in Persia, there are large quantities of *Neft-gil*, as it is called, which is nearly pure paraffin. The hot climate of the Caspian is favorable for such a result. *Secondly:* there may be a loss of hydrogen from its combination with the oxygen of the atmosphere to form water, which escapes. Thus the oils of the Naphtha series may change into those of the Ethylene or Benzole series. *Thirdly:* there may be an oxidation of the hydrocarbon of the oils, producing asphaltum or more coal-like substances, like albertite.

The word naphtha is from the Persian, *nafata*, to exude; and petroleum from the Greek, *petros*, rock, and the Latin, *oleum*, oil.

Hatchettite.—Mountain Tallow. Hatchettine.

Like soft wax in appearance and hardness, of a yellowish white to greenish yellow color.

Composition. Related to paraffin.

From the coal-measures of Glamorganshire in Wales.

Ozocerite. Like wax or spermaceti in consistence; soluble in ether. The original was from Moldavia; along with another wax-like substance, called *Urpethite*, it constitutes the "mineral wax of Urpeth Colliery." *Zietrisikite* is like beeswax, and is insoluble in ether; from Moldavia. *Prosepnyte*, of the mercury mine, Wake Co., Cal., is near ozocerite. A large deposit of ozocerite, or a related material, is worked in Southern Utah.

Elaterite.—Mineral Caoutchouc. Elastic Bitumen.

In soft flexible masses, somewhat resembling caoutchouc or India-rubber. Color brownish black; sometimes orange-red by transmitted light. G. = 0·9–1·25. *Composition:*

Carbon 85·5, hydrogen 13·3 = 98·8. Burns readily with a yellow flame and bituminous odor.

Obs. From a lead-mine in Derbyshire, England, and a coal-mine at Montrelais. Has been found at Woodbury, Ct., in a bituminous limestone.

Fichtelite and *Hartite* are crystallized hydrocarbons, of the Camphene series; the former is mentioned from a log of *Pinus Australis* in Alabama. *Branchite, Dinite,* and *Ixolyte* are related to Hartite. *Könlite, Naphthalin,* and *Idrialite* are native species of the Benzole series. *Aragotite,* from California, is near Idrialite.

II. OXYGENATED HYDROCARBONS.

Amber.

In irregular masses. Color yellow, sometimes brownish or whitish; lustre resinous. Transparent to translucent. H. = 2–2·5. G. = 1·18. Electric by friction.

Amber is not a simple resin, but consists mainly (85 to 90 per cent.) of a resin which resists all solvents, called *Succinite,* and two other resins soluble in alcohol and ether, besides an oil, and 2½ to 6 per cent. of *Succinic acid.*

Obs. Occurs in the loose deposits of sand, etc., along coasts, especially those of Tertiary strata, in masses from a very small size to that of a man's head. In the Royal Museum at Berlin there is a mass weighing 18 pounds. Most abundant on the Baltic coast, especially between Königsberg and Memel; also on the Adriatic; in Poland; on the Sicilian coast near Catania; in France near Paris, in clay; in China. It has been found in the U. States, at Gay Head, Martha's Vineyard, and on Nantucket; Camden, and near Harrisonville (one mass 20×6×1 in.), N. J.; and at Cape Sable, near the Magothy River, Md.; Pitt Co., and other eastern counties, N. C.

It is supposed, with good reason, to be a vegetable resin altered somewhat chemically since burial, partly owing to acids of sulphur proceeding from decomposing pyrites or some other source. It often contains insects, and specimens of this kind are so highly prized as frequently to be imitated for the shops. Some of the insects appear evidently to have struggled after being entangled in the then viscous resin, and occasionally a leg or a wing is found some distance from the body, which had been detached in the effort to escape.

Amber is the *elektron* of the Greeks; from its becoming electric so readily when rubbed, it gave the name electricity to science. It was also called *succinum*, from the Greek *succum*, juice, because of its supposed vegetable origin.

It admits of a good polish, and is used for ornamental purposes, though not very much esteemed, as it is wanting in hardness and brilliancy of lustre, and moreover is easily imitated. It is much valued in Turkey for mouth-pieces to pipes.

Copalite, or Mineral Copal, *Gedanite*, *Walchowite*, *Neudorfite*, *Schraufite*, *Ambrite* (the New Zealand resin), *Euosmite*, *Scleretinite*, *Middletonite*, *Ajkite*, *Duxite*, *Krantzite*, *Siegburgite*, are some of the names of other fossil resins; *Geocerite*, and *Geomyricite*, of wax-like oxygenated species; *Guyaquillite*, *Bathvillite*, *Ionite* (from Ione valley, Cal.), of species not resinous in lustre; *Tasmanite* and *Dysodile*, of kinds containing several per cent. of sulphur. *Celestialite* is a probable sulpho-hydrocarbon from a meteorite. *Torbanite*, or Boghead coal, is related in composition to amber. *Wollongongite*, from Hartley (not Wollongong), Australia, looks like cannel coal, but is near *torbanite*.

Dopplerite. Elastic or partly jelly-like, and from a peat-bed. A similar material, from a peat-bed in Scranton, Pa., has been named *Phytocollite*.

Hofmannite. White efflorescence on lignite; in tabular crystals; fuses easily to an oily fluid, and burns with a bright flame. Formula $C_{20}H_{36}O$. From near Siena, Italy.

III. ASPHALTUM AND MINERAL COALS.

Asphaltum.

Amorphous and pitch-like. Burning with a bright flame and melting at 90° to 100° F. Soluble mostly or wholly in camphene. A mixture of hydrocarbons, part of which are oxygenated.

Obs. Asphaltum is met with abundantly on the shores of the Dead Sea, and in the neighborhood of the Caspian. A remarkable locality occurs on the island of Trinidad, where there is a lake of it about a mile and half in circumference. The bitumen is solid and cold near the shores; but gradually increases in temperature and softness toward the centre, where it is boiling. The ascent to the lake from the sea, a distance of three quarters of a mile, is covered with the hardened pitch, on which trees and vegetation flourish, and here and there, about Point La Braye, the masses of pitch look like black rocks among the foliage.

Occurs also in South America about similar lakes in Peru, where it is used for pitching boats; in California on the coast of Santa Barbara. Large deposits occur in sandstone in Albania. *Uintahite*, from Uintah Mts., Utah, is similar.

Albertite.

Coal-like in hardness, but little soluble in camphene, and only imperfectly fusing when heated; but having the lustre of asphaltum, and softening a little in boiling water. H.= 1–2. G.= 1·097.

Fills fissures in the Subcarboniferous rocks near Hillsborough, Nova Scotia; supposed to have been derived from the hydrocarbon of the adjoining rock, and to have been oxidized at the time it was formed and filled the fissure.

Grahamite. A related material from West Virginia, 20 miles south of Parkersburg (also from Huasteca, Mexico). H.= 2; G.= 1·145; soluble mostly in camphene, but melt sonly imperfectly; an analysis afforded Carbon 76·45, hydrogen 7·82, oxygen (with traces of nitrogen) 13·46, ash 2·26 = 100.

MINERAL COAL.

Massive, uncrystalline. Color black or brown; opaque. Brittle or imperfectly sectile. H. = 0·5–2 5. G. = 1·2–1·80.

Composition. Carbon, with some oxygen and hydrogen, more or less moisture, and traces also of nitrogen, besides some earthy material which constitutes the *ash*. The carbon, or part of it, is in chemical combination with the hydrogen and oxygen. Often contains some occluded marsh gas, whose escape, as pressure is removed, is one source of the gas of coal-mines.

Coals differ in the amount of volatile ingredients given off when heated. These ingredients, besides moisture and some sulphur, are hydrocarbon oils and gas, derived from the same class of insoluble hydrocarbons that is the source of the oil of shales and other rocks.

VARIETIES.

1. *Anthracite.* (*Glance coal, Stone coal*). Lustre high, not resinous, sometimes submetallic. Color gray-black. H. = 2–2·5. G. = 1·57–1·67, if pure. Fracture often

conchoidal. Good anthracite contains 78 to 88 per cent. of fixed carbon (83 about an average) 2 to 3·5 of hydrogen, 1·5 to 3·5 of oxygen with 4 to 12 p. c. of earthy impurities. The amount of volatile matter is but 3 to 7 p. c., and there is a trace of sulphur. Burns with a feeble blue flame. The kind yielding the most volatile ingredients is called *free-burning* anthracite.

2. *Bituminous coal.* Color and powder black. Lustre usually somewhat resinous. H. = 1·5–2. G. = 1·2–1·4, if pure; the Pittsburg, 1·23–1·28. Contains usually 75 to 85 p. c. of carbon, 4 to 6 of hydrogen, 4 to 15 of oxygen, with mostly 2 to 9 p. c. of moisture. The volatile carbohydrogen ingredients 20 to 45 p. c., with 50 to over 60 in some kinds; sulphur in the best coals below 1 p. c., but often 2 to 2·5. Ash impurities 1·4–7·5 p. c.; average 5 or 6 p. c.; less than in anthracite, because anthracite was made out of bituminous coal by the expulsion of volatile ingredients—a condensing process. Burns with a bright yellow flame. Yields little to, or colors slightly, if at all, a potash solution.

Caking Coal includes that part of bituminous coal which softens when heated and becomes viscid, so that adjoining pieces unite into a solid mass. It burns readily with a lively yellow flame, but requires frequent stirring to prevent its agglutinating, and so clogging the fire. *Non-caking* coal resembles the caking in appearance, but does not soften and cake. The chemical difference between caking and non-caking coal is not understood.

3. *Cannel Coal.* Very compact and even in texture, with little lustre, and fracture large conchoidal. Takes fire readily, and burns without melting with a yellow flame, and has hence been used for candles—whence the name. Volatile carbohydrogen compounds given out when heated amount to 40 to 50 p. c., and even 60; and hence valued for the manufacture of gas as well as for fuel; also yields much mineral oil. Cannel coal is often made into inkstands and other similar articles.

4. *Brown Coal* (often called *Lignite*). Color black to brownish black; of powder, brown. Contains 15 to 20 p. c. of oxygen, and often 8 to 10 p. c. of hygrometric moisture; fixed carbon mostly 52 to 65 p. c. Gives a brownish or brownish red color to a solution of potash. Usually non-caking. The kinds having more or less of the structure of

wood are called *lignite;* and in these kinds, the oxygen present may be 25 to over 30 p. c., and the moisture 15 to 20 p. c. Between the brown coals and bituminous coal there is a gradual passage in constitution and in color of powder.

Jet resembles cannel coal, but is harder, of a deeper black and higher lustre. It receives a brilliant polish, and is set in jewelry. It is the *Gagates* of Dioscorides and Pliny, a name derived from the river Gagas, in Syria, near the mouth of which it was found, and the origin of the term jet now in use. Occurs in the Lower Oölite in Yorkshire.

Native Coke resembles somewhat artificial *coke*, but is more compact, and some varieties of it afford a considerable amount of bitumen. Occurs at the Edgehill mines near Richmond, Virginia, according to Genth, who attributes its origin to the action of a trap eruption on bituminous coal.

The following are a few analyses of bituminous coals, etc., the moisture excluded:

		Carbon.	Hydr.	Oxyg.	Nitr.	Sulph.	Ash.
1	Caking Coal, Kentucky	74·45	4·93	13·08	1·03	0·91	5·00
2	Caking Coal, Nelsonville, O.	73·80	5·79	16·58	1·52	0·41	1·90
3	Caking Coal, South Wales	82·56	5·36	8·22	1·65	0 75	1·46
4	Caking Coal, Northumberland	78·69	6·00	10·07	2·37	1·51	1·36
5	Non-caking, Kentucky	77·89	5·42	12·57	1·82	3·00	2·00
6	Non-caking, "Black Coal," Ind.	82·70	4·77	9·39	1·62	0·45	1·07
7	Non-caking, Briar Hill, O.	78·94	5·92	11·50	1·58	0·56	1·45
8	Non-caking, S. Staffordshire	76·40	4·62	17·43	....	0·55	1·55
9	Non-caking, Scotland	76·08	5 31	13·33	2·09	1·23	1·96
10	Cannel Coal, Breckenridge	68·13	6·49	5·83	2·27	2·48	12·30
11	Cannel Coal, Wigan	80·07	5·53	8·10	2·12	1·50	2·70
12	Cannel Coal, "Torbanite"	64·02	8·90	5·66	0·55	0·50	20·32
13	Albertite, Nova Scotia	86·04	8·96	1·97	2·93	*trace*	0·10
14	Brown Coal, Bovey	66·31	5·63	22·86	0·57	2·36	2·27
15	Brown Coal, Wittenberg	64·07	5·03	27·55	....	....	3·85
16	Brown Coal, Carbon, Wy.	73·55	4·17	17·20	1·93	1·18	1·86
17	Brown Coal, Carbon, Wy.	75·20	4·74	10·37	1·37	1·11	7·20
18	Peat, light brown (imperfect)	50·86	5·80	42·57	0·77	....	....
19	Peat, dark brown	59·47	6·52	31·51	2·51	....	....
20	Peat, black	59·70	5·70	33·04	1·56	....	....
21	Peat, black	59·71	5·27	32·07	2·59	....	....

It is now well established that mineral coal is mainly of vegetable origin, and that the accumulations out of which the coal-beds were made were very similar in character, though not in kinds of plants, to the peat-beds of the present day. Peat is vegetation which has undergone, in part, the change to coal; and in some cases it has become *brown coal.* The conditions of change are somewhat different from

those of the beds of good coal, since, in the case of the peat, the air has access, while in that of the coal the air was more or less excluded by overlying strata; and the more perfect the exclusion, other things equal, the better the coal. As the composition of mineral coal is closely related to that of mineral oils, the explanation of the origin of the latter, given on page 346, suffices to illustrate also the origin of the former. With a less complete exclusion of the air, oxygenated hydrocarbon compounds, like coal, would be a natural result.

The "Mineral Charcoal" of coal beds differs little in composition from ordinary bituminous coal; there is less hydrogen and oxygen. Rowney obtained, for that of Glasgow and Fifeshire, Carbon 82·97, 74·71; hydrogen 3·34, 2·74; oxygen 7·59, 7 67; ash 6 08, 14·86. The nitrogen is included with the oxygen; it was 0·75 in the Glasgow charcoal. Exclusive of the ash, the composition is Carbon 88·36, 87·78; hydrogen 3·56, 3·21; oxygen 7·28, 9·01. It has a fibrous look, and occurs covering the surfaces between layers of coal, and has been observed in coal of all ages. It is soft, and soils the fingers like charcoal; one variety of it is a dry powder.

The ordinary *impurities* of coal, making up its ash, are silica, a little potash and soda, and sometimes alumina, with often oxide of iron, more or less pyrite or iron sulphide; besides, in the less pure kinds, more or less clay or shale. The amount of ash does not ordinarily exceed 8 per cent., but it is sometimes 30 per cent.; and rarely it is less than 5 per cent. When not over 3 or 4 per cent. the whole may have come from the plants which contributed the most of the material of the coal, since the Lycopods have much alumina and lime sulphate in the ash, and the Equiseta much silica.

There is present, in most coal, traces of iron sulphide (pyrite, marcasite, or pyrrhotite), sufficient to give sulphur fumes to the gases from the burning coal, and sometimes enough to make the coal valueless in metallurgical operations. Some thin layers are occasionally full of concretionary pyrite. The sulphur was derived from the plants or from animal life in the waters. Sulphur also occurs, in some coal beds, as a constituent of a resinous substance; and Wormley has shown that part of the sulphur in the Ohio coals is in some analogous state, there being not iron enough present to take the whole into combination.

The average amount of ash in eighty-eight coals from the southern half of Ohio, according to Wormley, is 4·718 per cent.; in sixty-six coals from the northern half, 5·120; in all, from both regions, 4·891; or, omitting ten, having more than ten per cent. of ash, the average is 4·28. In eleven Ohio cannels, the average amount of ash was 12·827. The moisture in the Ohio coals, according to the analyses of Wormley, varies from 1·10 to 9·10 per cent. of the coal. In the Pittsburg coal (see analysis 8, above), the best of the bituminous, the amount of ash is 3 to 4·5 p. c., of moisture 1·3–1·5 p. c., of sulphur less than 0·25 p. c.

The volatile ingredients of bituminous coal when purified are the gas used in illumination. It consists of marsh-gas and hydrogen (near 80 p. c. of the two) with other heavier hydrocarbon vapors; some carbon oxide, usually two per cent. or so of moisture, with traces of carbon dioxide and nitrogen.

The value of coal as fuel, supposing its impurities excluded, depends on its density, the amount of moisture present, the amount of oxygen present.

If 100 pounds of coal contain 20 per cent. of oxygen, this oxygen is 20 pounds of incombustible material; which serves, it is true, to produce combustion in the other ingredients, but in this only does work which atmospheric oxygen may do as well; and further, it produces water by combination with hydrogen of the coal and so wastes part of the fuel.

If the 100 pounds contain 10 per cent. of moisture, this is 10 pounds of incombustible material, which uses the heat derived from the combustion of the other ingredients in order to take the form of vapor and escape.

If much impurity—ash—is present, so that a slag is formed by the fusion, the heat used in producing and sustaining this fusion is so much lost to the furnace.

Moreover, the hydrocarbon gases that escape, producing flame, take up and dissipate much heat.

On account of the conditions stated, anthracite is the best fuel for producing high heat. But for making steam in boilers flame is desirable, and this requires that the coal should contain more hydrogen than exists in anthracite; the semi-anthracite ranks among the best in this respect, since it burns with flame and practically no smoke; hence it is sometimes called "steam coal." Most bituminous coals contain too much hydrogen, or yield, on heating, too much of volatile hydrocarbons, for the most economical production of steam, or for metallurgical purposes, and hence the process adopted of subjecting the coal (the caking kind only is so used) to partial half-smothered combustion, and obtaining thus what is called *coke*. The coking drives off also from an eighth to a fourth of the sulphur present as pyrite or otherwise. The coke obtained is usually about 60 to 70 p. c. by weight of the coal used, but is of greater bulk.

The calorific power of a coal—dependent on the number of pounds of water that may be evaporated in the complete combustion of a given amount of the coal—may be calculated from the amount of combustible material, in the form of hydrogen and carbon, that is not lost, during the burning, from combination with the oxygen of the coal.

Since 1 part by weight of hydrogen combines, in the combustion, with 8 of oxygen to form water, an anthracite consisting, ash excluded, of 100 of carbon to 2·84 of hydrogen and 1·74 of oxygen, will have 2·62 of "disposable hydrogen," the 1·74 of oxygen carrying off 1·74 ÷ 8 or 0·22 p. c. of the hydrogen; and a bituminous coal, consisting of 100 carbon to 6·12 of hydrogen and 21·23 of oxygen, will have 3·47 of "disposable hydrogen," the 21·23 of oxygen carrying off 2·65 of the hydrogen. If then the coal contained no impurities, and the combustion were complete (union with oxygen, converting all the carbon to carbon dioxide and all the hydrogen to water), and there were

no *loss* of heat by radiation or otherwise, the amount of heat it would generate, or its pyrogenic power, would be directly deduced from that of one pound of carbon 2731° C., and an equal weight of hydrogen 2750° C. This gives only a theoretical result, since the loss of heat in practice is large, and from several sources, as already indicated. But the amount of "disposable" hydrogen determines the value of the coal in gas-production. In Wigan Cannel there are only about 8 per cent. of oxygen, and hence 4·5 p. c. of "disposable" hydrogen; while in Boghead Cannel, or Torbanite, the "disposable" hydrogen is over 8 per cent.

Mineral coal occurs in extensive beds or layers, interstratified with different rock strata. The associate rocks are usually clay shales (or slaty beds) and sandstones; and the sandstones are occasionally coarse grit rocks or conglomerates. There are sometimes also beds of limestone alternating with the other deposits.

Coal-beds vary in thickness from a fraction of an inch to 50 feet. The thickness of a bed may increase or diminish much in the course of a few miles, or the coal may become too shaly to work.

The areas of the "coal-measures" of the Carboniferous era, in the United States, are as follows:

1. A small area in Rhode Island, continued northward into Massachusetts.

2. A large area in Nova Scotia and New Brunswick, stretching eastward and westward from the head of the Bay of Fundy.

These two areas are now separated; but it is probable that they were once united along the region, now submerged, of the Bay of Fundy and Massachusetts Bay.

3. The Alleghany Region, which commences at the north on the southern borders of New York, and stretches southwestward across Pennsylvania, West Virginia, and Tennessee to Alabama, and westward over part of Eastern Ohio, Kentucky, Tennessee, and a small portion of Mississippi. It may underlie the Tertiary and Cretaceous rocks of Mississippi and other Southern States, and so have a much greater extension in that direction than that of its present surface distribution. To the north, the Cincinnati "uplift," an area of Silurian rocks extending from Lake Erie over Cincinnati to Tennessee, forms the western boundary.

4. The Michigan coal area, an isolated area wholly confined within the lower peninsula of Michigan.

5. The Eastern Interior area, covering nearly two thirds of Illinois, and parts of Indiana and Kentucky.

6. The Western Interior area, covering a large part of Missouri, and extending north into Iowa, and southward, with interruptions, through Arkansas into Texas, and westward into Kansas and Nebraska.

The Illinois and Missouri areas are connected now only through the underlying Subcarboniferous rocks of the age; but it is probable that formerly the coal-fields stretched across the channel of the Mississippi, and that the present separation is due to erosion along the valley.

Rocks of the Carboniferous period extend over large portions of the Rocky Mountain area, but they are mostly limestones, and are barren of coal.

The extent of the coal-bearing area of these Carboniferous regions is approximately as follows:

Rhode Island area	500 square miles.
Alleghany area	59,000 square miles.
Michigan area	6,700 square miles.
Illinois, Indiana, West Kentucky	47,000 square miles.
Missouri, Iowa, Kansas, Arkansas, Texas	78,000 square miles.
Nova Scotia and New Brunswick	18,000 square miles.

The whole area in the United States is over 190,000 square miles, and in North America about 208,000. Of the 190,000 square miles perhaps 120,000 have workable beds of coal.

Anthracite is the coal of Rhode Island, and of the areas in Central Pennsylvania, from the Pottsville or Schuylkill coal-field to the Lackawanna field, while the coal of Pittsburg, and of all the great coal-fields of the Interior basin, is *bituminous*, excepting a small area in Arkansas. Anthracite belongs especially to regions of upturned rocks, and bituminous coal to those where the beds are little disturbed. In the area between the anthracite region of Central Pennsylvania and the *bituminous* of Western, and farther south, the coal is *semi-bituminous*, as in Broad Top, Pennsylvania, and the Cumberland coal-field in Western Maryland, the volatile matters yielded by it being 15 to 20 per cent. The more western parts of the anthracite coal-fields afford the free-burning anthracite, or semi-anthracite, as at Trevorton, Shamokin, and Birch Creek.

The coal formation of the Carboniferous age in Europe has great thickness of rocks and coal in Great Britain, much less in Spain, France, and Germany, and a large surface, with little thickness of coal, in Russia. It exists, also, and includes workable coal-beds, in China, and also in India, Japan, and Australia; but, in part, the formations in these latter regions are Permian and Triassic or Jurassic. No coal of the Carboniferous era has yet been found in South America, Africa, or Asiatic Russia. The proportion of coal-beds to area in different parts of Europe has been stated as follows: in France, 1-100th of the surface; in Spain, 1-50th; in Belgium, 1-20th; in Great Britain, 1-10th. But, while the coal area in Great Britain is about 12,000 square miles, that of Spain is 4000, that of France about 2000, and that of Belgium 518.

The amount of coal in exposed Carboniferous coal-fields of Great Britain, within 4000 feet of the surface, and regarded as workable, as deduced from investigations made by a Royal Commission in 1866–71, was reported in 1878 to be over 90,000,000,000 tons; more than a third of this in South Wales; a fifth in Yorkshire and Derbyshire; a ninth in Northumberland and Durham; nearly as much in Scotland; and as much also in Somersetshire, combined with that in Lancashire and Cheshire; and the rest, about 2-15ths of the whole, in other coal-areas. Besides this, it is estimated that there are over 56,000,000,000 tons of available coal underneath the Permian and other formations, making in all about 146,500,000,000 tons, which is "1070 times the amount of the present annual output of 125,000,000 tons."

Mineral coal of later age than the true Carboniferous era occurs in

various parts of the world. Besides Australia and India, Triassic or Jurassic coal, of the bituminous variety, occurs in thick workable beds in the vicinity of Richmond, Va., and has been worked in the Deep River and Dan River regions, N. C. In Scotland, at Brora in Sutherlandshire, there is a bed of Oölitic coal. Coal of the Cretaceous and Tertiary eras constitutes important beds in various parts of the Rocky Mountain region, in the vicinity of the Pacific Railroad and elsewhere. Some of the prominent localities are: In Utah, at Evanston and Coalville (in the valley of Weber River), etc.; in Wyoming, at Carbon, 140 miles from Cheyenne; at Hallville, 142 miles farther west; at Black Butte station, on Bitter Creek; on Bear River, etc.; in the Uintah Basin, near Brush Creek, 6 miles from Green River; in Colorado, at Golden City, 15 miles west of Denver, on Ralston Creek, Coal Creek, S. Boulder Creek and elsewhere; in N. Mexico, at the Old Placer Mines in the San Lazare Mountains, etc.; and in British America, N. of Montana. The coal is of the bituminous or semibituminous kind, part of it true brown coal, but the rest more correctly referred to true bituminous coal. At the Old Placer Mines, New Mexico, the coal is in part anthracite, affording 88 to 91 per cent. of fixed carbon; the region is one of upturned and altered rocks, like the anthracite region of Pennsylvania. Other similar beds occur toward the Pacific coast, the most valuable of them in Washington Territory, near Seattle and at Bellingham Bay; also on Coos Bay, Oregon; on Vancouver and adjacent islands in British Columbia. Some anthracite, like that of N. Mexico in origin, occurs on the Queen Charlotte Islands.

I. CATALOGUE OF AMERICAN LOCALITIES OF MINERALS.

THE following catalogue of American localities of minerals is introduced as a Supplement to the Descriptions of Minerals. Its object is to aid the mineralogical tourist in selecting his routes and arranging the plan of his journeys. Only important localities, affording cabinet specimens, are in general included; and the *names of those minerals which are obtainable in good specimens are distinguished by italics.* When the name is not italicized, the mineral occurs only sparingly or of poor quality. When the specimens to be procured are remarkably good, an exclamation-mark (!) is added.

MAINE.

ALBANY.—*Beryl! green and black tourmaline, garnet, feldspar, rose quartz,* rutile.

ANDOVER.—See RUMFORD.

AUBURN, w. part, near Minot line.—*Lepidolite, amblygonite (hebronite),* cassiterite, colorless, *green,* blue, and black *tourmaline! apatite* (Mt. Apatite).

BATH.—Vesuvianite, *garnet,* magnetite, graphite.

BETHEL.—*Cinnamon garnet,* calcite, sphene, beryl, pyroxene, hornblende, epidote, graphite, talc, pyrite, arsenopyrite, magnetite.

BINGHAM.—*Massive pyrite,* galenite, blende, andalusite.

BLUE HILL BAY.—*Arsenical iron, molybdenite! galenite, apatite! fluorite!* black tourmaline (Long Cove), black oxide of manganese (Osgood's farm), *rhodonite,* bog manganese, wolframite.

BOWDOIN.—*Rose quartz.*

BOWDOINHAM.—*Beryl,* molybdenite.

BRUNSWICK.—*Green mica, garnet! black tourmaline!* molybdenite, epidote, *calcite, muscovite, feldspar,* beryl.

BUCKFIELD.—*Garnet* (estates of Waterman and Lowe), *muscovite! tourmaline!* magnetite.

CAMDAGE FARM.—(Near the tide mills), molybdenite, wolframite.

CAMDEN.—*Macle, galenite,* epidote, black tourmaline, pyrite, talc, magnetite.

CANTON.—*Chrysoberyl.*

CARMEL (Penobscot Co.).—Stibnite, pyrite, macle.

CORINNA.—*Pyrite, arsenopyrite.*

DEER ISLE.—*Serpentine, verd-antique,* asbestus, diallage, magnetite.

DEXTER.—Galenite, pyrite, blende, chalcopyrite, green talc.

DIXFIELD.—Native copperas, graphite.

FARMINGTON.—(Norton's Ledge), *pyrite,* graphite, garnet, staurolite.

FRANKLIN PLANTATION.—Beryl.

FREEPORT.—*Rose quartz, garnet,* feldspar, scapolite, graphite, *muscovite.*

FRYEBURG.—*Garnet,* beryl.

WEST GARDINER, along the Litchfield border. See LITCHFIELD.

GEORGETOWN.—(Parker's Island), *beryl!* black tourmaline.

GORHAM.—Andalusite.

GREENWOOD.—Graphite, black manganese, *beryl! arsenopyrite,* cassiterite, *mica, rose quartz, garnet,* corundum, albite, zircon, molybdenite, magnetite, copperas.

HEBRON, 7 m. s. of Mt. Mica in Paris.—*Lepidolite, amblygonite (hebronite), rubellite!* indicolite, *green tourmaline,* damourite (as altered tourmaline), *mica, beryl, apatite, albite, childrenite, cookeite, cassiterite,* arsenopyrite, idocrase.

LINNÆUS.—Hematite, limonite, *pyrite,* bog-iron.

LITCHFIELD.—*Sodalite, cancrinite, elæolite, zircon,* hydronephelite, spodumene, muscovite, pyrrhotite (from bowlders).

LOVELL.—Beryl.

LUBEC LEAD MINES.—*Galenite, chalcopyrite, blende.*

MACHIASPORT.—*Jasper,* epidote, laumontite.

MADAWASKA SETTLEMENTS.—*Vivianite.*

MINOT.—*Beryl, smoky quartz.*

MONMOUTH.—Actinolite, apatite, *elæolite, zircon,* staurolite, plumose mica, beryl, rutile.

MT. ABRAHAM.—*Andalusite,* staurolite.

NORWAY.—*Chrysoberyl!* molybdenite, *beryl, rose quartz, orthoclase, albite, lepidolite,* cinnamon garnet, triphylite (lithiophilite), cookeite, cassiterite, amblygonite.

ORR'S ISLAND.—*Steatite,* garnet, andalusite.

OXFORD—*Garnet, beryl,* apatite, wad, zircon, *muscovite, orthoclase.*

PARIS, on Mt. Mica.—*Green! red! black,* and *blue tourmaline! mica! lepidolite!* feldspar, *albite, quartz crystals! rose quartz, cassiterite, amblygonite,* columbite, zircon, brookite, beryl, smoky quartz, spodumene, *cookeite,* leucopyrite, triphylite.

PARSONSFIELD.—*Vesuvianite! yellow garnet, pargasite, adularia,* labradorite (cryst.), *scapolite,* galenite, blende, chalcopyrite.

PERU.—*Crystallized pyrite,* columbite, beryl, spodumene, triphylite (cryst.), *chrysoberyl.*

PHIPPSBURG —*Yellow garnet! manganesian garnet, vesuvianite, pargasite, axinite, laumontite!* chabazite, an ore of cerium?

POLAND.—Vesuvianite, smoky quartz, cinnamon garnet.

PORTLAND.—*Prehnite,* actinolite, garnet, epidote, amethyst, calcite.

POWNAL.—*Black tourmaline, feldspar,* scapolite, pyrite, actinolite, apatite, rose quartz.

RAYMOND.—*Magnetite, scapolite, pyroxene, lepidolite, tremolite,* hornblende, epidote, orthoclase, yellow garnet, pyrite, vesuvianite.

ROCKLAND.—Hematite, tremolite, *quartz,* wad, *talc.*

RUMFORD.—On n. slope of Black Mtn., *tourmaline* (red), *lepidolite, spodumene,* cookeite, *yellow garnet, vesuvianite, pyroxene,* apatite, scapolite, cassiterite, amblygonite.

SANFORD, York Co.—*Vesuvianite!* albite, calcite, molybdenite, epidote, black tourmaline, labradorite.

SEARSMONT.—*Andalusite,* tourmaline.

SOUTH BERWICK.—Chiastolite.
STANDISH.—*Columbite! tourmaline.*
STONEHAM.—*Columbite, chrysoberyl, herderite, topaz, mica* (curved), triplite.
STOWE.—*Chrysoberyl,* fibrolite.
STREAKED MOUNTAIN.—*Beryl! black tourmaline, mica, garnet.*
THOMASTON.—*Calcite, tremolite, hornblende,* sphene, arsenical iron (Owl's Head), black manganese (Dodge's Mountain), *thomsonite, talc,* blende, pyrite, galenite.
TOPSHAM.—*Quartz,* galenite, blende, tungstite? beryl, apatite, molybdenite, columbite.
UNION.—Magnetite, bog-ore.
WALES.—Axinite in bowlder, alum, copperas.
WATERVILLE.—*Crystallized pyrite.*
WINDHAM (near the bridge).—*Staurolite, spodumene, garnet,* beryl, amethyst, *cyanite,* tourmaline.
WINSLOW.—Cassiterite.
WINTHROP.—*Staurolite,* pyrite, hornblende, garnet, copperas.
WOODSTOCK.—*Graphite,* hematite, prehnite, epidote, calcite.
YORK.—*Beryl,* vivianite, oxide of manganese.

The localities of lepidolite, green and red tourmalines, etc., in albite veins, occur in western Maine along a S. E. line from the Rangeley Lakes to a point between Brunswick and Portland, in Rumford, Paris, Norway, Hebron, and Auburn, about 40 m. in length.

NEW HAMPSHIRE.

ACWORTH.—*Beryl! mica! tourmaline, orthoclase, albite, rose quartz, columbite!* cyanite, autunite.
ALEXANDRIA.—*Muscovite.*
ALSTEAD.—*Mica! albite, black tourmaline, molybdenite,* andalusite, staurolite.
AMHERST.—*Vesuvianite, yellow garnet,* pargasite, amethyst, pyroxene, magnetite.
BARTLETT.—*Magnetite, hematite,* quartz crystals, danalite, limonite, *smoky quartz.*
BATH.—Galenite, chalcopyrite, alum.
BEDFORD.—Tremolite, epidote, graphite, mica, tourmaline, alum, quartz, graphite.
BELLOWS FALLS.—Cyanite, staurolite, prehnite.
BENTON.—*Epidote,* beryl, magnetite.
BERLIN.—*Chalcopyrite,* pyrite, magnetite, hornblende.
BRISTOL.—*Graphite,* galenite.
CAMPTON.—*Beryl!*
CANAAN.—Gold in quartz veins and alluvium, *garnet.*
CHARLESTOWN.—*Staurolite, andalusite,* prehnite, cyanite.
CONCORD.—Fibrolite.
CORNISH.—*Rutile in quartz!* (rare), *staurolite,* stibnite.
CROYDON.—*Iolite!* chalcopyrite, pyrite, *pyrrhotite, sphalerite.*
ENFIELD.—Gold, galenite, staurolite, green quartz, ripidolite.
FRANCESTON.—*Soapstone, arsenopyrite,* quartz crystals.

FRANCONIA.—Arsenopyrite, chalcopyrite.
GARDNER MTN.—*Chalcopyrite, pyrite, galenite.*
GILMANTON.—Tremolite, epidote, muscovite, tourmaline, limonite, quartz crystals.
GOSHEN.—*Graphite,* black tourmaline.
GRAFTON.—Muscovite (quarried at Glass Hill, 2 m. S. of Orange Summit), *albite!* blue, green, and yellow *beryls!* (1 m. S. of O. Summit), *tourmaline, garnets, triphylite, apatite,* fluorite, columbite, molybdenite, rhodonite.
GRANTHAM.—*Gray staurolite!*
GROTON.—Arsenopyrite, *beryl, muscovite* crystals, orthoclase, columbite.
HANOVER.—*Garnet, black tourmaline, quartz, cyanite,* epidote, anorthite, cyanite, zoisite.
HAVERHILL.—*Garnet! arsenopyrite, native arsenic,* galenite, blende, pyrite, chalcopyrite, magnetite, marcasite, steatite.
HEBRON.—*Beryl,* andalusite, graphite.
HINSDALE.—*Rhodonite,* molybdenite, indicolite, black tourmaline.
JACKSON.—Drusy quartz, tin ore, *arsenopyrite,* native arsenic, *fluorite,* apatite, *magnetite, molybdenite,* wolframite, chalcopyrite.
JAFFREY (Monadnock Mt.).—*Cyanite,* limonite.
KEENE.—*Graphite,* soapstone, milky quartz. rose quartz.
LANDAFF.—*Molybdenite,* magnetite, pyrrhotite.
LEBANON.—Limonite, arsenopyrite, galenite, magnetite, pyrite.
LISBON.—*Staurolite, garnets, magnetite, hornblende, epidote, zoisite,* hematite, arsenopyrite, galenite, gold, ankerite. Franconia ironmine, *Hornblende, epidote, zoisite, hematite, magnetite, garnets, arsenopyrite* (danaite), *molybdenite,* prehnite, cyanite.
LITTLETON.—Ankerite, gold, bornite, chalcopyrite, malachite, menaccanite, chlorite.
LYMAN.—Gold, *arsenopyrite, ankerite,* dolomite, galenite, pyrite, pyrrhotite.
LYME.—*Cyanite* (N. W. part), *black tourmaline,* rutile, pyrite, chalcopyrite (E. of E. village), stibnite, *molybdenite,* cassiterite, staurolite.
MADISON.—*Galenite, blende,* chalcopyrite, limonite.
MERRIMACK.—*Rutile!* (in gneiss nodules in granite vein).
MIDDLETOWN.—*Rutile,* arsenopyrite.
MILAN.—*Chalcopyrite, galenite,* sphalerite.
MILLSFIELD.—Beryl, garnets.
MONADNOCK MOUNTAIN.—Andalusite, hornblende, garnet, graphite, tourmaline, orthoclase, fibrolite.
NEW LONDON.—Beryl, *molybdenite, muscovite.*
NEWPORT.—*Molybdenite,* staurolite.
ORANGE.—*Blue beryls!* Orange Summit, chrysoberyl, *muscovite* (W. side of mountain), *albite,* tourmaline, apatite, galenite, limonite.
ORFORD.—*Brown tourmaline* (obtained with difficulty), *steatite, rutile, cyanite,* menaccanite, garnet, graphite, molybdenite, pyrrhotite, *melaconite,* chalcopyrite, chalcocite, malachite, galenite, *ripidolite.*
PIERMONT.—*Micaceous hematite,* barite, mica, apatite.
PLYMOUTH.—Columbite, beryl.
RICHMOND.—*Iolite,* rutile, steatite, pyrite, anthophyllite, talc.
RYE.—*Chiastolite* (at Boar's Head, in bowlders).

SADDLEBACK MT.—Black tourmaline, garnet, spinel.
SHELBURNE.—*Galenite, black blende, chalcopyrite, pyrite,* pyrolusite.
SPRINGFIELD.—Beryls (eight inches diameter), *manganesian garnets! black tourmaline!* in mica schist, *albite, mica,* rose quartz.
SULLIVAN.—*Tourmaline* (black) in quartz, beryl.
SURRY.—Amethyst, galenite, tourmaline, cyanite.
SUTTON.—*Graphite, beryl.*
UNITY (estate of James Neal).—Chalcopyrite, *pyrite, chlorophyllite,* green mica, actinolite, garnet, magnetite, tourmaline.
WALPOLE.—Macle, staurolite, mica, graphite.
WARE.—Graphite.
WARREN.—*Chalcopyrite, blende, epidote,* quartz, *pyrite, tremolite, galenite, rutile, talc,* molybdenite, *cinnamon stone! pyroxene,* hornblende, *beryl, cyanite,* tourmaline (massive), pyrite.
WATERVILLE.—Labradorite, chrysolite, amethyst.
WESTMORELAND (south part).—*Molybdenite! apatite! blue feldspar, bog manganese* (north village), quartz, amethyst, *fluorite,* chalcopyrite, molybdite.
WHITE MTS. (Notch near the "Crawford House").—Green *fluorite,* quartz crystals, black tourmaline, andalusite, amethyst, amazonstone.
WHITEFIELD.—*Molybdenite.*
WINCHESTER.—Pyrolusite, *rhodonite,* rhodochrosite, *magnetite,* pyrite, *spodumene, tourmaline.*

VERMONT.

ATHENS.—*Steatite, rhomb spar,* actinolite, garnet.
BALTIMORE.—*Serpentine, pyrite!*
BARNET.—Graphite.
BELVIDERE.—Steatite, chlorite.
BENNINGTON.—*Pyrolusite,* limonite.
BERKSHIRE.—*Epidote,* hematite, magnetite.
BETHEL.—*Actinolite!* talc, chlorite, octahedral iron, *rutile, brown spar in steatite.*
BRANDON.—Pyrolusite, psilomelane, limonite, lignite, kaolinite, statuary marble; graphite, chalcopyrite.
BRATTLEBOROUGH.—Black tourmaline in quartz, mica, zoisite, rutile, actinolite, scapolite, spodumene, roofing slate.
BRIDGEWATER.—*Talc, dolomite, magnetite,* steatite, chlorite, gold, native copper, blende, galenite, blue spinel, chalcopyrite.
BRISTOL.—*Rutile,* limonite, manganese ores, magnetite.
BROOKFIELD.—Arsenopyrite, *pyrite.*
CABOT.—Garnet, staurolite, hornblende, *albite.*
CAVENDISH.—Garnet, *serpentine, talc, steatite, tourmaline, asbestus, tremolite.*
CHESTER.—*Asbestus,* feldspar, chlorite, *quartz.*
CHITTENDEN.—Psilomelane, pyrolusite, limonite, *hematite* and *magnetite,* galenite, iolite.
COLCHESTER.—Limonite, iron sand, jasper, alum.
CORINTH.—Chalcopyrite (has been mined), pyrrhotite, pyrite, rutile.

COVENTRY.—Rhodonite.
CRAFTSBURY.—Mica in concretions, calcite, rutile.
DERBY.—Mica (*adamsite*).
ELY.—*Chalcopyrite*, pyrite.
FAIR HAVEN.—*Roofing slate*, pyrite.
FARMINGTON.—*Andalusite*.
FLETCHER.—Pyrite, magnetite, acicular tourmaline.
GRAFTON.—The Grafton *steatite* quarry is in Athens; *quartz*, actinolite.
GUILFORD.—Scapolite, rutile.
HARTFORD.—Calcite, *pyrite! cyanite*, quartz, tourmaline.
IRASBURGH.—Rhodonite, *psilomelane*.
JAY.—*Chromite, serpentine*, amianthus, dolomite.
LOWELL.—Picrosmine, amianthus, serpentine, cerolite, talc, chlorite.
MARLBORO'.—*Rhomb spar, steatite, garnet, magnetite*, chlorite.
MIDDLESEX.—Rutile! (exhausted).
MONKTON.—*Pyrolusite*, limonite, feldspar.
MORETOWN.—*Smoky quartz! steatite*, talc, wad, rutile, serpentine.
MOUNT HOLLY.—*Asbestus*, chlorite.
NEW FANE.—*Glassy* and *asbestiform actinolite, steatite, green quartz* (called chrysoprase at the locality), chalcedony, drusy quartz, *garnet, chromic and titanic iron, rhomb spar*, serpentine, rutile.
NORWICH.—*Actinolite, feldspar, brown spar* in talc, *cyanite*, zoisite, chalcopyrite, pyrite.
PITTSFORD.—Limonite, manganese ores, *statuary marble!*
PLYMOUTH.—Siderite, magnetite, hematite, *gold*, galenite.
PUTNEY.—Fluorite, *limonite, rutile* and *zoisite* in bowlders, staurolite.
READING.—*Glassy actinolite* in talc.
READSBORO'.—*Glassy actinolite, steatite*, hematite.
ROCHESTER.—Rutile, hematite cryst., *magnetite* in chlorite slate.
ROCKINGHAM (Bellows Falls).—Cyanite, indicolite, feldspar, tourmaline, fluorite, calcite, prehnite, staurolite.
ROXBURY.—*Dolomite, talc*, serpentine, asbestus, quartz.
RUTLAND.—*Magnesite, white marble*, hematite, serpentine.
SHARON.—*Quartz crystals*, cyanite.
SHOREHAM.—*Pyrite*, black marble, calcite.
STRAFFORD.—Magnetite and *chalcopyrite* (has been worked), native copper, hornblende, copperas.
THETFORD.—Blende, *galenite, cyanite*, chrysolite in basalt, pyrrhotite, *feldspar, roofing slate*, steatite, garnet.
TOWNSHEND.—*Actinolite*, black mica, *talc*, steatite, feldspar.
TROY.—*Magnetite*, talc, serpentine, picrosmine, amianthus, *steatite*, one mile southeast of village of South Troy, on the farm of Mr. Pierce, east side of Missisco, chromite, zaratite.
VERSHIRE.—*Pyrite*, chalcopyrite, tourmaline, arsenopyrite, quartz.
WARDSBORO'.—*Zoisite*, tourmaline, *tremolite*, hematite.
WARREN.—Actinolite, magnetite, wad, serpentine.
WATERBURY.—Arsenopyrite, chalcopyrite, *rutile, quartz*, serpentine.
WATERVILLE.—*Steatite*, actinolite, talc.
WEATHERSFIELD.—*Steatite*, hematite, *pyrite*, tremolite.
WESTFIELD.—*Steatite*, chromite, serpentine,

WESTMINSTER.—Zoisite in bowlders.
WINDHAM.—*Glassy actinolite, steatite, garnet,* serpentine.
WOODSTOCK.—*Quartz crystals,* garnet, zoisite.

MASSACHUSETTS.

ATHOL.—*Allanite,* fibrolite (?), *epidote!* babingtonite ?
AUBURN.—*Masonite.*
BARRE.—*Rutile! mica, pyrite, beryl, feldspar, garnet.*
GREAT BARRINGTON.—Tremolite.
BEDFORD.—*Garnet.*
BELCHERTON.—Allanite.
BERNARDSTON.—Magnetite at loc. of crinoidal limestone.
BEVERLY.—Columbite, *green feldspar,* cassiterite.
BLANFORD.—*Serpentine, anthophyllite, actinolite! chromite,* cyanite, rose quartz in bowlders.
BOLTON.—*Scapolite! petalite, sphene, pyroxene, nuttalite, diopside. boltonite,* apatite, magnesite, rhomb spar, *allanite, yttrocerite!* spinel.
BOXBOROUGH.—*Scapolite,* spinel, *garnet,* augite, actinolite, apatite.
BRIMFIELD (road leading to Warren).—*Iolite,* andalusite, adularia, molybdenite, mica, garnet.
CARLISLE.—*Tourmaline, garnet! scapolite.* actinolite.
CHARLESTOWN.—*Prehnite, laumontite,* stilbite, chabazite, quartz crystals, melanolite.
CHELMSFORD.—*Scapolite* (chelmsfordite), *chondrodite, blue spinel, amianthus!* rose quartz.
CHESTER.—*Hornblende, scapolite, zoisite, spodumene, indicolite,* apatite, magnetite, chromite, stilbite, heulandite, analcite, and chabazite. At the Emery Mine, Chester Factories.—*Corundum, margarite, diaspore,* epidote, corundophilite, chloritoid, tourmaline, *menaccanite,* rutile, biotite, *cyanite,* amesite.
CHESTERFIELD.—*Blue, green, and red tourmaline, cleavelandite* (albite), lepidolite, *smoky quartz, microlite, spodumene, cyanite,* apatite, *beryl, garnet, quartz crystals, staurolite,* cassiterite, *columbite,* zoisite, uranite, brookite (eumanite), scheelite, anthophyllite, bornite.
CONWAY.—Pyrolusite, fluorite, zoisite, *rutile!* native alum, galenite.
CUMMINGTON.—*Rhodonite!* cummingtonite (hornblende), marcasite, *garnet.*
DEERFIELD.—Chabazite, heulandite, stilbite, datolite, prehnite, natrolite, analcite, calcite, fluorite, diabantite, saponite, amethyst, carnelian, chalcedony, *agate,* pyrite, malachite.
FITCHBURG (Pearl Hill).—*Beryl, staurolite!* garnets, molybdenite.
FOXBOROUGH.—*Pyrite, anthracite.*
FRANKLIN.—Amethyst.
GLOUCESTER.—*Danalite.*
GOSHEN.—*Mica, albite, spodumene! blue and green tourmaline, beryl, zoisite,* smoky quartz, columbite, tin ore, galenite, beryl (goshenite), cymatolite (mixture of albite and muscovite).
GREENFIELD (in sandstone quarry, ½ m. E. of village).—Allophane.
HATFIELD.—Barite, galenite, blende, chalcopyrite, quartz crystals.

HAWLEY.—*Micaceous iron*, massive pyrite, magnetite, zoisite.
HEATH.—*Pyrite, zoisite.*
HINSDALE.—Limonite, apatite, zoisite.
HUBBARDSTON.—*Massive pyrite.*
HUNTINGTON (name changed from Norwich).—*Apatite! black tourmaline, beryl, spodumene! triphylite* (altered), blende, quartz crystals, cassiterite.
LANCASTER.—*Cyanite, chiastolite!* apatite, staurolite, pinite, andalusite.
LEE.—*Tremolite, sphene*, chondrodite in South Lee.
LEVERETT.—Barite, galenite, blende, chalcopyrite.
LEYDEN.—*Zoisite, rutile.*
MARBLEHEAD.—In zircon syenyte, sodalite, elæolite.
MARTHA'S VINEYARD.—Limonite, amber, radiated pyrite.
MENDON.—*Mica!* chlorite.
MIDDLEFIELD.—*Glassy actinolite, rhomb spar, steatite, serpentine, feldspar;* drusy quartz, apatite, zoisite, nacrite, chalcedony, *talc!* deweylite.
MILBURY.—*Vermiculite.*
NEW BRAINTREE.—*Black tourmaline.*
NEWBURY.—*Serpentine*, chrysotile, *epidote, massive garnet*, siderite.
NEWBURYPORT.—*Serpentine, nemalite*, uranite.—Argentiferous galenite, tetrahedrite, chalcopyrite, pyrargyrite, etc.
NORTHFIELD.—*Columbite*, fibrolite, cyanite.
NORWICH.—See HUNTINGTON.
PALMER (Three Rivers).—*Feldspar*, prehnite, calcite.
PELHAM.—*Asbestus*, serpentine, *quartz crystals*, beryl, *molybdenite, green hornstone*, epidote, amethyst, corundum, vermiculite (pelhamite).
PLAINFIELD.—*Cummingtonite, prolusite, rhodonite.*
RICHMOND.—Limonite, *gibbsite! allophane.*
ROCKPORT (near the extremity of C. Ann).—*Danalite, cryophyllite, annite, cyrtolite* (altered zircon), amazonstone, fergusonite, lepidomelane, *green* and *white orthoclase.*
ROWE.—Epidote, talc; at Davis mine, *pyrite*, chalcopyrite, *gahnite*, zoisite.
SOUTH ROYALSTON.—*Beryl!* (now obtained with difficulty), *mica! feldspar!* allanite. Four miles beyond old loc., on farm of Solomon Heywood, *mica! beryl! feldspar!* menaccanite.
RUSSEL.—*Garnet! mica*, serpentine, beryl, galenite, chalcopyrite.
SALEM.—Cancrinite, sodalite, elæolite, zircon.
SHEFFIELD.—*Asbestus*, pyrite, native alum, pyrolusite, rutile.
SHELBURNE.—Rutile.
SHUTESBURY (east of Locke's Pond).—*Molybdenite.*
SOUTHAMPTON.—Galenite, cerussite, anglesite, *wulfenite*, fluorite, barite, pyrite, chalcopyrite, blende, phosgenite, pyromorphite, stolzite, chrysocolla.
STERLING.—*Spodumene. chiastolite*, siderite, arsenopyrite, *blende*, galenite, chalcopyrite, pyrite, sterlingite (damourite).
STONEHAM.—*Nephrite.*
STURBRIDGE.—*Graphite*, garnet, apatite, bog-ore.
SWAMPSCOT.—*Orthite*, feldspar.
TAUNTON (one mile south).—Paracolumbite (titanic iron).

TURNER'S FALLS (Conn. River).—Chalcopyrite, prehnite, chlorite, siderite, malachite.

TYRINGHAM and on borders of OTIS.—*Pyroxene, scapolite,* chondrodite, *sphene, hornblende, spherostilbite.*

WARWICK.—*Massive garnet, radiated black tourmaline, magnetite,* beryl, epidote.

WASHINGTON.—*Graphite.*

WESTFIELD.—*Schaller spar* (diallage), *serpentine, steatite,* cyanite, scapolite, actinolite.

WESTFORD.—*Andalusite!*

WEST HAMPTON.—Galenite, *argentine, pseudomorphous quartz.*

WEST STOCKBRIDGE.—*Limonite,* fibrous pyrolusite, *siderite.*

WILLIAMSBURG.—*Zoisite,* pseudomorphous quartz, apatite, rose and smoky quartz, galenite, pyrolusite, chalcopyrite.

WINDSOR.—*Zoisite,* actinolite, *rutile!*

WORCESTER.—Arsenopyrite, idocrase, pyroxene, garnet, amianthus, bucholzite, siderite, galenite.

WORTHINGTON.—*Cyanite.*

ZOAR.—Bitter spar, *talc.*

RHODE ISLAND.

BRISTOL.—*Amethyst.*

CRANSTON.—Actinolite in talc, graphite, cyanite, mica, melanterite.

CUMBERLAND.—*Manganese, epidote, actinolite,* garnet, titaniferous iron, magnetite, hematite, chalcopyrite, bornite, malachite, azurite, calcite, apatite, feldspar, zoisite, mica, quartz crystals, ilvaite.

DIAMOND HILL.—Quartz crystals, hematite.

FOSTER.—*Cyanite,* hematite.

GLOUCESTER.—*Magnetite* in chlorite slate, feldspar.

JOHNSTON.—Talc, brown spar, calcite, garnet, epidote, pyrite, hematite, magnetite, chalcopyrite, malachite, azurite.

NATIC.—See WARWICK.

NEWPORT.—*Serpentine,* quartz crystals.

PORTSMOUTH.—*Anthracite,* graphite, asbestus, pyrite, chalcopyrite.

SMITHFIELD.—*Dolomite, calcite, bitter spar, siderite, nacrite,* serpentine (bowenite), tremolite, asbestus, quartz, magnetite in chlorite schist, *talc!* octahedrite, feldspar, beryl.

VALLEY FALLS.—Graphite, pyrite, hematite.

WARWICK (Natic village).—*Masonite,* garnet, graphite, bog-ore.

WESTERLY.—Menaccanite.

WOONSOCKET.—Cyanite.

CONNECTICUT.

BERLIN.—Barite, datolite, blende, quartz crystals.

BOLTON.—Staurolite, chalcopyrite.

BRANCHVILLE.—Pyroxene, *garnet. Albite, microcline,* amblygonite, *spodumene! cymatolite, margarodite* (curved), eosphorite, triploidite, reddingite, dickinsonite, lithiophilite, *rhodochrosite,* fairfieldite, *apa-*

tite, microlite, *columbite!* garnet, pyrite, tourmaline, staurolite, *uraninite*, *torbernite*, *autunite*, vivianite, eucryptite, chabazite, stilbite, heulandite.

BRISTOL.—*Chalcocite*, *chalcopyrite*, barite, *bornite*, *allophane*, pyromorphite, *calcite*, malachite, galenite, quartz.

BROOKFIELD.—Galenite, calamine, *blende*, spodumene, pyrrhotite, chalcopyrite.

CANAAN.—*Tremolite* and white *pyroxene!* in dolomite, canaanite (massive pyroxene).

CHATHAM.—Arsenopyrite, smaltite, cloanthite (chathamite), scorodite, niccolite, *beryl*, erythrite.

CHESHIRE.—*Barite!* chalcocite, bornite, malachite, kaolin, natrolite, prehnite, chabazite, datolite.

CHESTER.—*Sillimanite!* zircon, epidote.

CORNWALL.—*Graphite*, pyroxene, actinolite, sphene, scapolite.

DANBURY.—*Danburite* with *oligoclase* (formerly), brown tourmaline, orthoclase, pyroxene, parathorite.

FARMINGTON.—Prehnite, chabazite, agate, native copper, *diabantite*.

HADDAM.—*Chrysoberyl!* (not accessible), *beryl*, *epidote*, *tourmaline*, orthoclase, *garnet*, *iolite! chlorophyllite! oligoclase*, *automolite*, *magnetite*, *adularia*, apatite, *columbite!* (hermannolite), zircon (calyptolite), *mica*, pyrite, marcasite, *molybdenite*, allanite, bismuth ochre, bismutite.

HADLYME.—Chabazite and stilbite in gneiss.

HARTFORD.—*Datolite* (Rocky Hill quarry).

LITCHFIELD.—*Cyanite* with corundum, apatite, and andalusite, *menaccanite* (washingtonite), chalcopyrite, diaspore, niccoliferous pyrrhotite, margarodite, staurolite.

LYME.—Garnet, sunstone, microcline.

MERIDEN.—*Datolite* (greenish), diabantite.

MIDDLEFIELD FALLS.—Datolite, chlorite, etc., in amygdaloid.

MIDDLETOWN.—*Mica*, *albite*, *feldspar*, *columbite! prehnite*, *garnet*, beryl, topaz, uranite, apatite, pitchblende, *lepidolite* with green and red tourmaline; at lead-mine formerly *galenite*, *chalcopyrite*, blende, quartz, *calcite*, fluorite, pyrite sometimes capillary.

MILFORD.—Sahlite, pyroxene, asbestus, verd-antique marble.

NEW HAVEN.—Serpentine, sahlite, stilbite, laumontite.

NEWTOWN.—*Cyanite*, *diaspore*, *rutile*, damourite.

NORWICH.—*Sillimanite*, *monazite! iolite*, corundum, feldspar.

PORTLAND.—Orthoclase, *albite*, *muscovite*, *biotite*, *beryl*, tourmaline, columbite, apatite; at Pelton's feldspar quarry, monazite.

PLYMOUTH.—Galenite, *heulandite*, *fluorite*, *chloryphyllite!* garnet.

ROARING BROOK (Cheshire).—*Datolite!* calcite, prehnite, saponite.

ROXBURY.—*Siderite*, *blende*, *pyrite! galenite*, quartz, chalcopyrite, arsenopyrite, limonite.

SALISBURY.—Limonite, *pyrolusite*, manganite, triplite, *turgite*, scovillite, staurolite.

SEYMOUR.—Arsenopyrite, pyrite.

SIMSBURY.—Chalcocite, green malachite.

SOUTHBURY.—Rose quartz, laumontite, prehnite, calcite, barite.

SOUTHINGTON.—Barite, datolite, asteriated quartz crystals, diabantite.

STAFFORD.—Massive pyrite, alum, copperas.
TARIFFVILLE.—*Datolite!*
TRUMBULL and MONROE.—*Chlorophane, topaz* (vein not open), *beryl*, diaspore, pyrrhotite, pyrite, scheelite, *wolframite* (pseudomorph of scheelite), native bismuth, tungstic acid, siderite, arsenopyrite, argentiferous galenite, blende, scapolite, *tourmaline, garnet*, albite, augite, graphic tellurium (?), *margarodite.*
WASHINGTON.—*Tripolite, menaccanite!* (washingtonite of Shepard), rhodochrosite, natrolite, *andalusite* (New Preston), cyanite.
WATERTOWN, near the Naugatuck.—White sahlite, monazite.
WEST FARMS.—Asbestus.
WILLIMANTIC.—*Topaz, monazite, ripidolite.*

NEW YORK.

ALBANY CO.—BETHLEHEM.—Calcite, stalactite, calcareous sinter, snowy gypsum.
COEYMAN'S LANDING.—Gypsum, epsom salt, *quartz* crystals at Crystal Hill, 3 m. S. of Albany.
WATERVLIET.—*Quartz crystals*, yellow drusy quartz.
CAYUGA CO.—AUBURN.—Celestite, calcite, fluor spar, epsomite.
SPRINGPORT.—At Thompson's plaster-beds, *sulphur, selenite.*
UNION SPRINGS.—*Selenite*, gypsum.
CLINTON CO.—ARNOLD IRON MINE.—*Magnetite*, epidote, molybdenite.
FINCH ORE BED.—*Calcite, green* and purple fluor.
PLATTSBURG.—Nugget of platinum in drift.
COLUMBIA CO.—ANCRAM.—Lead-mine, galenite, blende, wulfenite, chalcopyrite.
CANAAN.—Chalcocite, chalcopyrite, argentiferous galenite.
COPAKE.—Limonite (large ore-beds).
HUDSON.—*Selenite.*
NEW LEBANON.—Nitrogen springs, epsom salt, brown spar, *wad, siderite.*
DUTCHESS CO.—AMENIA.—Dolomite, *limonite, turgite, siderite.*
DOVER.—Dolomite, tremolite, garnet, (Foss ore-bed) *limonite*, staurolite.
FISHKILL.—Dolomite; near Peckville, talc, asbestus, *graphite, hornblende*, augite, *actinolite*, hydrous anthophyllite, *limonite.*
NORTH EAST.—Chalcocite, chalcopyrite, galenite, blende.
UNION VALE.—At the Clove mine, *gibbsite, limonite.*
ESSEX CO.—ALEXANDRIA.—Kirby's graphite mine, *graphite, pyroxene, scapolite*, sphene.
CROWN POINT.—*Apatite* (eupyrchroite of *Emmons*), *brown tourmaline!* in the apatite, chlorite, quartz crystals, calcite, pyrite; S. of J. C. Hammond's house, *garnet, scapolite*, chalcopyrite, *aventurine feldspar*, zircon, magnetite (Peru), epidote, mica.
KEENE.—Scapolite.
LEWIS.—*Tabular spar, colophonite*, garnet, *labradorite, hornblende*, actinolite; 10 m. S. of Keeseville, arsenopyrite.
LONG POND.—Apatite, *garnet, pyroxene*, idocrase, *coccolite! scapolite*, magnetite, *blue calcite.*

McINTYRE.—*Labradorite*, garnet, *magnetite*.

MORIAH, at Sandford Ore Bed.—*Magnetite*, apatite, *allanite!* lanthanite, actinolite, and feldspar; at Fisher Ore Bed, *magnetite*, feldspar, quartz; at Hall Ore Bed, or "New Ore bed," *magnetite, zircons;* on Mill brook, *calcite*, pyroxene, hornblende, albite; in the town of Moriah, magnetite, *black mica;* Barton Hill Ore-bed, *albite*.

NEWCOMB.—*Labradorite*, feldspar, magnetite, hypersthene.

PORT HENRY.—*Brown tourmaline*, black tourmaline enclosing orthoclase, *mica, rose quartz, serpentine, green* and *black pyroxene*, hornblende, *cryst. pyrite*, graphite, wollastonite, pyrrhotite, *adularia; phlogopite!* at Cheever Ore Bed, with magnetite and serpentine; in Champlain iron region, uranothorite.

ROGER'S ROCK.—*Graphite, wollastonite, garnet, feldspar*, adularia, *pyroxene, sphene*, coccolite.

SCHROON.—*Calcite*, pyroxene, *chondrodite*.

TICONDEROGA.—*Graphite! pyroxene, sahlite, sphene*, black tourmaline, cacoxenite? (Mt. Defiance).

WESTPORT.—Labradorite, prehnite, magnetite.

WILLSBORO'.—*Wollastonite, colophonite*, garnet, *green coccolite*, hornblende.

GREENE CO.—DIAMOND HILL.—Quartz crystals.

HERKIMER CO.—FAIRFIELD.—*Quartz crystals*, fetid barite.

LITTLE FALLS.—*Quartz crystals!* barite, calcite, *smoky quartz;* 1 m. S. of Little Falls, calcite, brown spar, feldspar.

MIDDLEVILLE.—*Quartz crystals! calcite*, brown and pearl spar.

NEWPORT.—*Quartz crystals*.

SALISBURY.—*Quartz crystals!* blende, galenite, pyrite, chalcopyrite.

STARK.—Fibrous celestite, *gypsum*.

JEFFERSON CO.—ADAMS.—Fluor, calc tufa, barite.

ALEXANDRIA.—On S. E. bank of Muscolonge Lake, fluorite (exhausted), *phlogopite*, chalcopyrite, apatite; on High Island, in the St. Lawrence River, feldspar, *tourmaline*, hornblende, *orthoclase*, celestite.

ANTWERP.—Sterling iron-mine, hematite, *chalcodite*, siderite, *millerite, red hematite*, crystallized quartz, *yellow aragonite*, niccoliferous pyrite, *quartz crystals*, pyrite; at Oxbow, *calcite!* porous coralloidal heavy spar; near Vrooman's lake, *calcite!* vesuvianite, *phlogopite! pyroxene, sphene*, fluorite, pyrite, chalcopyrite; also *feldspar, bog-iron ore*, scapolite (farm of Eggleson), *serpentine*, tourmaline (yellow, rare).

BROWNSVILLE.—Celestite, calcite (4 m. from Watertown).

NATURAL BRIDGE.—*Gieseckite! steatite pseudomorphous* after pyroxene, apatite.

NEW CONNECTICUT.—*Sphene, brown phlogopite*.

OMAR.—*Beryl, feldspar*, hematite.

PHILADELPHIA.—*Garnets* on Indian River, in the village.

PILLAR POINT.—*Massive barite* (exhausted).

THERESA.—*Fluorite, calcite*, hematite, hornblende, *quartz crystal*, serpentine (associated with hematite), celestite, strontianite.

WATERTOWN.—*Tremolite, agaric mineral*, calc tufa, celestite.

WILNA.—One mile N. of Natural Bridge, *calcite*.

LEWIS CO.—DIANA (localities mostly near junction of crystalline and sedimentary rocks, and 2 m. from Natural Bridge).—*Scapolite!* wollastonite, *green coccolite, feldspar, tremolite, pyroxene! sphene!* mica, *quartz crystals*, pyrite, pyrrhotite, *blue calcite*, serpentine, *rensselaerite*, zircon, graphite, chlorite, hematite, bog-ore, *apatite.*

GREIG.—*Magnetite*, pyrite.

LOWVILLE.—*Calcite*, fluorite, pyrite, galenite, blende, calc tufa.

MARTINSBURGH.—Wad, galenite, etc. (formerly), *calcite.*

MONROE CO.—ROCHESTER.—*Pearl spar*, calcite, snowy gypsum, fluor, celestite, galenite, blende, barite, hornstone.

MONTGOMERY CO.—PALATINE.—*Quartz crystals*, drusy quartz, anthracite, hornstone, agate, garnet.

ROOT.—*Drusy quartz, blende*, barite, stalactite, galenite, pyrite.

NEW YORK CO.—KINGSBRIDGE.—*Tremolite, pyroxene, mica, tourmaline*, pyrite.

NEW YORK.—*Serpentine, amianthus*, actinolite, *pyroxene*, hydrous anthophyllite, garnet, staurolite, molybdenite, graphite, *chlorite*, beryl, jasper, *necronite*, feldspar. In the excavations for the 4th Avenue tunnel, 1875, *harmotome*, stilbite, chabazite, heulandite, etc.

NIAGARA CO.—LEWISTON.—*Epsomite.*

LOCKPORT.—*Celestite, calcite, selenite, anhydrite, fluorite, dolomite*, sphalerite.

NIAGARA FALLS.—*Calcite*, fluorite, blende. *dolomite.*

ONEIDA CO.—BOONVILLE.—*Calcite, wollastonite, coccolite.*

CLINTON.—*Blende, lenticular* hematite in the Clinton group, strontianite, celestite, the former covering the latter.

ONONDAGA CO.—CAMILLUS.—*Selenite* and *fibrous gypsum.*

SYRACUSE.—*Serpentine*, celestite, selenite, barite.

ORANGE CO.—CORNWALL —*Zircon, chondrodite, hornblende, spinel, feldspar, epidote*, hudsonite, menaccanite, *serpentine*, coccolite.

DEER PARK.—*Cryst. pyrite*, galenite.

MONROE.—*Mica! sphene! garnet*, colophonite, *epidote, chondrodite, allanite*, bucholzite, brown spar, *spinel*, hornblende, talc, menaccanite, *pyrrhotite*, pyrite, chromite, *graphite*, rastolyte, moronolite; Wilks and O'Neill Mine, aragonite, *magnetite*, dimagnetite (pseud.?), jenkinsite, *asbestus*, serpentine, *mica, hortonolite;* TWO PONDS, *pyroxene! chondrodite, hornblende, scapolite! zircon, sphene*, apatite; GREENWOOD FURNACE, *chondrodite, pyroxene! mica, hornblende, spinel, scapolite, biotite!* menaccanite.

FOREST OF DEAN.—*Pyroxene, spinel*, zircon, scapolite, hornblende.

TOWN OF WARWICK, WARWICK VILLAGE.—*Spinel! zircon, serpentine! brown spar, pyroxene! hornblende! pseudomorphous steatite, feldspar!* (Rock Hill), menaccanite, *clintonite*, tourmaline (R. H.), *rutile, sphene*, molybdenite, arsenopyrite, marcasite, pyrite, yellow iron sinter, quartz, jasper, mica, coccolite.

AMITY.—*Spinel! garnet, scapolite, hornblende, vesuvianite, epidote! clintonite! magnetite, tourmaline*, warwickite, *apatite, chondrodite, talc! pyroxene!* rutile, menaccanite, *zircon, corundum, feldspar*, sphene, calcite, serpentine, schiller spar (?), silvery mica.

EDENVILLE.—*Apatite, chondrodite! hair-brown hornblende!* tremolite, *spinel, tourmaline, warwickite, pyroxene, sphene, mica, feldspar,*

arsenopyrite, orpiment, *rutile*, menaccanite, scorodite, chalcopyrite, *leucopyrite* (or löllingite), allanite.

WEST POINT.—*Feldspar*, *mica*, scapolite, *sphene*, *hornblende*, allanite.

PUTNAM CO.—BREWSTER, Tilly Foster Iron Mine.—*Chondrodite! magnetite*, *dolomite*, *serpentine pseudomorphs*, *brucite*, *enstatite*, *ripidolite*, biotite, actinolite, *pyrrhotite*, fluorite, albite, epidote, sphene, *apophyllite*.

ANTHONY'S NOSE, at top, pyrite, pyrrhotite, pyroxene, hornblende, magnetite.

CARMEL (Brown's quarry).—Anthophyllite, arsenopyrite, epidote.

COLD SPRING.—Sphene, epidote.

PATTERSON.—*White pyroxene! calcite*, *asbestus*, *tremolite*, dolomite, massive pyrite.

PHILLIPSTOWN.—*Tremolite*, *amianthus*, *serpentine*, *sphene*, *diopside*, *green coccolite*, hornblende, *scapolite*, stilbite, mica, laumontite, gurhofite, calcite, magnetite, chromite.

PHILLIPS Ore Bed.—Hyalite, *actinolite*, *massive pyrite*.

RICHMOND CO.—ROSSVILLE.—Lignite, *cryst. pyrite*.

QUARANTINE.—*Asbestus*, *amianthus*, aragonite, *dolomite*, *gurhofite*, brucite, serpentine, *talc*, magnesite.

ROCKLAND CO.—CALDWELL.—*Calcite*.

LADENTOWN.—Zircon, malachite, cuprite.

PIERMONT.—Datolite, stilbite, apophyllite, pectolite, prehnite, thomsonite, calcite, chabazite.

ST. LAWRENCE CO.—CANTON.—*Massive pyrite*, *calcite*, brown tourmaline, *sphene*, *serpentine*, talc, *rensselaerite*, pyroxene, hematite, chalcopyrite.

DE KALB.—*Hornblende*, barite, *fluorite*, *tremolite*, *tourmaline*, *white tourmaline*, blende, graphite, pyroxene, diopside quartz (spongy), serpentine.

EDWARDS.—*Brown* and *silvery mica!* scapolite, apatite, *quartz crystals*, actinolite, *tremolite!* hematite, serpentine, magnetite.

FINE.—*Black mica*, hornblende.

FOWLER.—*Barite*, *quartz crystals!* hematite, *blende*, galenite, tremolite, chalcedony, bog-ore, satin spar (assoc. with serpentine), pyrite, chalcopyrite, actinolite, *rensselaerite* (near Somerville).

GOUVERNEUR.—*Calcite! serpentine! hornblende! scapolite! orthoclase*, *tourmaline!* idocrase (1 m. S. of G.), pyroxene, malacolite, apatite, *rensselaerite*, serpentine, *sphene*, fluorite, barite (farm of Judge Dodge), black *mica*, phlogopite, *tremolite!* asbestus, hematite, graphite, vesuvianite (near Somerville in serpentine), *spinel*, houghite, scapolite, *phlogopite*, dolomite; ¼ m. W. of Somerville, *chondrodite*, spinel; 2 m. N. of Somerville, *apatite*, pyrite, *brown tourmaline!!*

HAMMOND.—*Apatite! zircon!* (farm of Mr. Hardy), *orthoclase* (loxocase), *pargasite*, barite, pyrite, purple fluorite, *tremolite*, *phlogopite*.

HERMON.—*Quartz crystals*, hematite, siderite, pargasite, pyroxene, serpentine, tourmaline, bog-iron ore.

MACOMB.—Blende, mica, *galenite* (on land of James Averill), sphene, peristerite.

MINERAL POINT, Morristown.—Fluorite, blende, galenite, *phlogopite* (Pope's Mills), barite.

OGDENSBURGH.—Labradorite.

PIERREPONT.—Tourmaline, sphene, scapolite, hornblende, pyroxene.

PITCAIRN.—Satin spar, associated with serpentine, titanite.

POTSDAM.—*Hornblende!;* eight miles from Potsdam, on road to Pierrepont, *feldspar, tourmaline, black mica,* hornblende.

ROSSIE (Iron Mines).—*Barite,* hematite, coralloidal aragonite (near Somerville), *quartz, pyrite, pearl spar;* ROSSIE Lead Mine, *calcite, galenite, pyrite, celestite,* chalcopyrite, hematite, cerussite, anglesite, *octahedral fluor, black phlogopite;* elsewhere in ROSSIE, *calcite,* barite, quartz crystals, chondrodite (near Yellow Lake), *feldspar! pargasite! apatite; pyroxene.* hornblende, sphene, zircon, *mica,* fluorite, serpentine, automolite, pearl spar, graphite.

RUSSEL.—*Pargasite,* hematite, *quartz* (dodec.), calcite, serpentine, rensselaerite, magnetite, *danburite!* with pyroxene, titanite, biotite, hornblende.

SARATOGA CO.—GREENFIELD.—*Chrysoberyl! garnet! tourmaline! mica, feldspar.* apatite, graphite, aragonite (in iron mines).

SCHOHARIE CO.—BALL'S CAVE, and others.—Calcite, stalactites.

CARLISLE.—*Fibrous barite, cryst. and fibrous calcite.*

SCHOHARIE.—Fibrous celestite, *strontianite! cryst. pyrite!*

SULLIVAN CO.—WURTZBORO'.—*Galenite, blende, pyrite, chalcopyrite.*

ULSTER CO.—ELLENVILLE.—*Galenite,* blende, *chalcopyrite! quartz! brookite.*

WARREN CO.—CALDWELL.—*Massive feldspar.*

CHESTER.—*Pyrite,* tourmaline, rutile, chalcopyrite.

DIAMOND ISLE (Lake George).—*Calcite, quartz crystals.*

JOHNSBURGH.—*Fluorite! zircon! graphite, serpentine, pyrite.*

WASHINGTON CO.—FORT ANN.—*Graphite,* serpentine.

GRANVILLE.—*Lamellar pyroxene,* massive feldspar, epidote.

WAYNE CO.—WOLCOTT.—Barite.

WESTCHESTER CO.—ANTHONY'S NOSE.—*Apatite,* pyrite, *calcite!* in large tabular crystals, grouped, and sometimes incrusted with drusy quartz.

CRUGER'S.—White pyroxene, hornblende, magnetite (with greenish spinel), staurolite, fibrolite.

DAVENPORT'S NECK.—*Serpentine,* garnet, sphene.

EASTCHESTER.—Blende, pyrite, chalcopyrite, dolomite.

HASTINGS.—*Tremolite, white pyroxene.*

NEW ROCHELLE.—*Serpentine,* quartz, *mica,* tremolite, garnet, magnesite.

PEEKSKILL.—Hornblende.

RYE.—*Serpentine, chlorite, black tourmatine,* tremolite.

SING SING.—*Pyroxene, tremolite, pyrite,* beryl, azurite, green malachite, cerussite, pyromophite, anglesite, vauquelinite, galenite, native silver, chalcopyrite.

WEST FARMS.—Apatite, tremolite, garnet, stilbite, heulandite, chabazite, epidote, sphene.

YONKERS.—*Tremolite*, apatite, calcite, analcite, *pyrite*, tourmaline.
YORKTOWN.—*Fibrolite*, *monazite*, magnetite.
WYOMING CO.—WYOMING.—Rock salt.

NEW JERSEY.

ANDOVER IRON MINE (Sussex Co.).—Willemite, brown garnet.
ALLENTOWN (Monmouth Co.).—*Vivianite*, *dufrenite*.
BELLVILLE.—Copper mines.
BERGEN.—*Calcite! datolite! pectolite! analcite*, *apophyllite! gmelinite*, *prehnite*, sphene, *stilbite*, *natrolite*, heulandite, laumontite, *chabazite*, pyrite, pseudomorphous steatite imitative of apophyllite, diabantite.
BRUNSWICK.—*Native copper*, *malachite*, *mountain leather*.
BRYAM.—Chondrodite, *spinel*, at Roseville, *epidote*.
CANTWELL'S BRIDGE (Newcastle Co.).—Vivianite.
DANVILLE (Jemmy Jump Ridge).—*Graphite*, chondrodite, augite.
FLEMINGTON.—*Copper mines*.
FRANKFORT.—*Serpentine*.
FRANKLIN and STERLING (Sussex Co.).—*Spinel! garnet! rhodonite! willemite! franklinite! zincite! gahnite! hornblende*, *tremolite*, *chondrodite*, *white scapolite*, *black tourmaline*, *epidote*, *mica*, actinolite, augite, sahlite, coccolite, asbestus, *jeffersonite* (augite), *calamine*, graphite, fluorite, beryl, galenite, serpentine, honey-colored sphene, quartz, chalcedony, amethyst, zircon, molybdenite, vivianite, *tephroite*, *rhodochrosite*, aragonite, *sussexite*, chalcophanite, rœpperite, calcozincite, vanuxemite, *gahnite*, hetærolite, pyrochroite. Also *algerite* in gran. limestone.
FRANKLIN and WARWICK MTS.—*Pyrite*.
GRIGGSTOWN and GREENBROOK.—Copper-mines.
HAMBURGH.—One mile north, *spinel! tourmaline*, *phlogopite*, *hornblende*, *limonite*, hematite.
HARRISONVILLE (Gloucester Co.).—*Amber*.
HOBOKEN.—Serpentine (marmolite), *brucite*, *nemalite* (or fibrous brucite), aragonite, dolomite.
HURDSTOWN.—*Apatite*, pyrrhotite, magnetite.
IMLAYSTOWN.—Vivianite.
LOCKWOOD.—*Graphite*, *chondrodite*, *talc*, *augite*, *quartz*, *green spinel*.
MONTVILLE (Morris Co.).—Serpentine, *chrysotile*.
MULLICA HILL (Gloucester Co.).—*Vivianite* lining belemnites and other fossils.
NEWTON.—*Spinel*, blue, pink, and white corundum, *mica*, vesuvianite, *hornblende*, *tourmaline*, *scapolite*, rutile, pyrite, talc, calcite, barite, *pseudomorphous steatite*.
PATTERSON.—*Datolite*.
ROSEVILLE (Sussex Co.).—*Epidote*.
VERNON.—Serpentine, spinel, hydrotalcite.
WEEHAWKEN.—*Natrolite*, *apophyllite*.

PENNSYLVANIA.*

ADAMS CO.—GETTYSBURG.—Epidote, fibrous and massive.

BEDFORD CO.—Bridgeport.—Barite.

BERKS CO.—MORGANTOWN.—At Jones's mines, 1 m. E. of Morgantown, *malachite*, native copper, *chrysocolla*, *magnetite*, allophane, pyrite, chalcopyrite, aurichalcite, melaconite, byssolite, aragonite, apatite, talc; 2 m. N. E. from Jones's mine, graphite, sphene; at Steele's mine, *magnetite*, micaceous iron, coccolite, brown garnet.

READING.—*Smoky quartz* crystals, *zircon*, stilbite, iron-ore; near Pricetown, zircon, allanite, epidote; at Eckhardt's Furnace, *allanite* with *zircon;* at Zion's Church, molybdenite; near Kutztown, in the Crystal Cave, stalactites; at Fritz Island, *apophyllite*, thomsonite, *chabazite*, calcite, azurite, *malachite*, magnetite, chalcopyrite, stibnite, prochlorite, precious serpentine.

BUCKS CO.—BRIDGEWATER STATION.—*Titanite.*

BUCKINGHAM TOWNSHIP.—Crystallized quartz; near New Hope, vesuvianite, epidote, barite.

SOUTHAMPTON.—Near Feasterville, in G. Vanarsdale's quarry, *graphite*, pyroxene, sahlite, coccolite, *sphene*, green mica, calcite, *wollastonite*, glassy feldspar sometimes opalescent, phlogopite, *blue quartz*, garnet, zircon, pyrite, moroxite, scapolite.

NEW BRITAIN.—Dolomite, galenite, blende, malachite.

CARBON CO.—SUMMIT HILL, in coal-mines.—*Kaolinite.*

CHESTER CO.—AVONDALE.—Asbestus, tremolite, garnet! opal, *beryl* (yellow)!

BIRMINGHAM TOWNSHIP.—Amethyst, serpentine.

EAST BRADFORD.—Near Buffington's bridge, on the Brandywine, green, blue, and gray cyanite, gray crystals loose in the soil; farms of Dr. Elwyn, Mrs. Foulke, Wm. Gibbons, and Saml. Entrikin, *amethyst;* at Strode's mill, aquacreptite, oligoclase, drusy quartz, *collyrite?* on Osborne's Hill, *wad*, *manganesian garnet* (massive), *sphene;* at Caleb Cope's lime quarry, *fetid dolomite*, necronite, blue cyanite, *talc;* near the Black Horse Inn, *indurated talc*, rutile; on Amos Davis's farm, *orthite!* near the paper-mill on the Brandywine, *zircon*, menaccanite, blue quartz.

WEST BRADFORD.—Near village of Marshalton, *green cyanite;* at the Chester County Poor-house limestone quarry, *chesterlite!* on dolomite, *rutile!* in acicular crystals, *damourite?* radiated on dolomite, *quartz crystals.*

CHARLESTOWN.—*Pyromorphite*, *cerussite*, *galenite*, quartz, amethyst.

NORTH COVENTRY.—Allanite, near Pughtown black garnets.

EAST GOSHEN.—Serpentine, *asbestus*, magnetite.

ELK.—Menaccanite with muscovite, chromite.

WEST GOSHEN.—On the Barrens, 1 m. N. of West Chester, serpentine, indurated talc, *deweylite*, *radiated magnesite*, aragonite, *staurolite*, asbestus; *zoisite* on hornblende at West Chester waterworks (not accessible at present).

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* See also the Report on the Mineralogy of Pennsylvania, by Dr. F. A. Genth, 1875.

NEW GARDEN.—At Nivin's limestone quarry, *brown and yellow tourmaline, necronite, aragonite, fibrolite, kaolinite,* tremolite.

KENNETT.—Actinolite, tremolite; on Wm. Cloud's farm, *sunstone!* at Pearce's old mill, *sunstone.*

EAST MARLBOROUGH.—On farm of Bailey & Brother, 1 m. S. of Unionville, *yellow* and white *tourmaline, chesterlite;* near Marlborough meeting-house, serpentine, *zircon* loose in the soil at Pusey's sawmill.

WEST MARLBOROUGH.—Near Logan's quarry, cyanite, yellow tourmaline, rutile; near Doe Run village, *tremolite:* in R. Baily's limestone quarry, 2½ m. S. W. of Unionville, *fibrous tremolite, cyanite.*

NEWLIN.—1½ m. N. E. of Unionville, *corundum!* often in loose crystals with a coating of steatite, *diaspore!,* spinel (black), picrolite, black *tourmaline* with flat pyramidal terminations in albite, *euphyllite, feldspar, beryl!* in one crystal weighing 51 lbs., pyrite, chloritoid, diallage, *oligoclase;* menaccanite, *clinochlore,* albite, *orthoclase,* halloysite, margarite, garnets, *beryl;* on J. Lesley's farm, *corundum,* a single mass weighing over 100 tons, *diaspore!;* in Edwards's limestone quarry, rutile; C. Passmore's farm, amethyst.

EAST NOTTINGHAM.—*Asbestus, chromite* in crystals, hallite.

WEST NOTTINGHAM.—At Scott's chrome-mine, *chromite, foliated talc,* marmolite, serpentine, *rhodochrome;* near Moro Phillips's chrome-mine, *asbestus;* at the magnesia quarry, *deweylite,* marmolite, magnesite, leelite, serpentine, chromite, meerschaum; near Fremont P. O., corundum.

WEST PIKELAND.—In iron-mines near Chester Springs, *turgite, hematite* (stalactitical and in geodes), göthite.

PENNSBURY.—On John Craig's farm, brown garnets, *mica;* on J. Dilworth's, near Fairville, *muscovite!* in Fairville, *sunstone;* near Brinton's Ford, *chondrodite, sphene, augite;* at Swain's quarry, orthoclase, muscovite containing magnetite.

POCOPSON.—Farms of J. Entrikin and J. B. Darlington, *amethyst.*

SADSBURY.—*Rutile!* crystals loose for 7 m. along the valley, near the village of Parkesburg; near Sadsbury village, *amethyst.*

SCHUYLKILL.—In railroad tunnel at PHŒNIXVILLE, *dolomite!,* quartz crystals, *calcite;* at the WHEATLEY, BROOKDALE, and CHESTER COUNTY LEAD-MINES (now abandoned, and good specimens not obtainable). 1½ m. S. of Phœnixville, *pyromorphite! cerussite! galenite, anglesite!* quartz crystals, chalcopyrite, barite, *fluorite* (white), *stolzite, wulfenite! calamine, vanadinite, blende! mimetite!* descloizite, göthite, chrysocolla, native copper, malachite, *azurite,* limonite, *calcite, sulphur,* pyrite, melaconite, pseudomalachite, gersdorffite, chalcocite ? covellite.

WILLISTOWN.—*Magnetite, chromite.*

WEST TOWN.—On the serpentine rocks, 3 m. S. of West Chester, *clinochlore! jefferisite!* actinolite.

WEST WHITELAND.—At Gen. Trimble's iron-mine (southeast), *stalactitic hematite! wavellite!!* in radiated stalactites, gibbsite.

WARWICK.—Elizabeth mine and Keim's mine 1 m. N. of Knauertown, *aplome garnet! micaceous hematite, pyrite* (octahedral), chalcopyrite massive and in crystals, magnetite, *brown garnet,* calcite,

byssolite! serpentine; near village of St. Mary's, magnetite (dodecahedral), *melanite, garnet, actinolite;* at Hopewell iron-mine, 1 m. N. W. of St. Mary's, *magnetite* in octahedral crystals.

YELLOW SPRINGS.—Allanite.

DAUPHIN CO.—NEAR HUMMERSTOWN.—Green garnets, cryst. *smoky quartz*, feldspar.

DELAWARE CO.—ASTON TOWNSHIP.—*Amethyst, corundum* (Village Green), *fibrolite*, black tourmaline, *margarite, sunstone, asbestus*, anthopyllite, steatite; Bridgewater Station, *Titanite*, in twins and translucent; at Peter's mill-dam in the creek, *pyrope garnet.*

BIRMINGHAM.—*Fibrolite, kaolin* (abundant), *rutile, amethyst;* at Bullock's old quarry, zircon, *bucholzite.*

CHESTER.—*Amethyst, black tourmaline, beryl, crystals of orthoclase, beryl, garnet, molybdenite, molybdite*, uraninite, *muscovite.*

CHICHESTER.—Near Trainer's mill-dam, *beryl*, tourmaline, *feldspar.*

CONCORD.—*Mica, feldspar, kaolin, drusy quartz, garnet, anthophyllite*, fibrolite, amethyst, *manganesian garnet*, meerschaum; in Green's creek, *pyrope garnet.*

DARBY.—*Blue* and *gray cyanite, beryl, garnet*, smoky quartz.

EDGEMONT.—*Amethyst;* 1 m. E. of Edgemont Hall, *rutile* in quartz.

LEIPERVILLE.—Garnet, zoisite, heulandite, leidyite, *beryl* (Deshong's qu), *black tourmaline.*

MARPLE.—*Tourmaline, andalusite*, amethyst, *actinolite, bronzite*, talc, *radiated actinolite* in talc, chromite, beryl, *menaccanite in quartz*, amethyst.

MIDDLETOWN.—*Amethyst, beryl*, black mica, *mica* dendritic with magnetite, *manganesian garnets!* some 3 inches in diameter, indurated talc, *rutile, mica, green quartz! anthophyllite*, radiated tourmaline, staurolite, titanic iron, fibrolite, serpentine; at Lenni, *chlorite*, green and bronze *vermiculite! green feldspar;* at Mineral Hill, crystals of *corundum*, some of 6 inches, *actinolite*, bronzite, *green feldspar, moonstone, sunstone*, magnesite, *chromite* (octahedrons), columbite, *beryl*, asbestus, rutile, melanosiderite, hallite; at Painter's Farm, *zircon* with oligoclase, tremolite, tourmaline; at Hibbard's Farm and at Fairlamb's Hill, chromite in brilliant octahedrons; John Smith farm, meerschaum.

NEWTOWN.—Serpentine, hematite, enstatite.

UPPER PROVIDENCE.—*Anthophyllite, radiated asbestus, andalusite, radiated actinolite*, tourmaline, *beryl, green feldspar, amethyst* (one of 7 lbs. from Morgan Hunter's farm), *andalusite!;* at Blue Hill, *blue quartz* in chlorite, *amianthus* in serpentine.

LOWER PROVIDENCE.—*Amethyst*, garnet, feldspar ! (large crystals).

RADNOR.—*Garnet*, marmolite, deweylite, chromite, asbestus, magnesite, picrolite, *bronzite.*

SPRINGFIELD.—*Andalusite, tourmaline*, beryl, titanic iron, garnet; on Fell's Laurel Hill, beryl, garnet; near Lewis's paper-mill, allophane, mica, albite.

WATERVILLE.—Near Chester and Upland, chabazite.

FRANKLIN CO.—LANCASTER STATION.—Barite.

HUNTINGDON CO.—Near FRANKSTOWN.—In a bed of a stream and on a hill-side, *fibrous celestite, quartz crystals.*

LANCASTER CO.—DRUMORE TOWNSHIP.—Quartz crystals.

FULTON.—At Wood's chrome mine, near Texas, *brucite!* zaratite (emerald nickel), *pennite! ripidolite! kämmererite! enstatite, bronzite, baltimorite, chromite,* williamsite, *chrysolite!* marmolite, *picrolite,* hydromagnesite, *dolomite,* magnesite, *aragonite,* calcite, serpentine, hematite, menaccanite, genthite, chrome-garnet, bronzite, millerite; at Low's mine, *hydromagnesite, brucite* (lancasterite), *picrolite,* magnesite, *williamsite, chromic iron,* talc, zaratite, baltimorite, serpentine, hematite; on M. Boice's farm, 1 m. N. W. of village, *pyrite,* enstatite; near Rock Springs, *chalcedony,* carnelian, *moss agate, green tourmaline* in talc, titanic iron, chromite, *octahedral magnetite in chlorite;* at Reynolds's old mine, calcite, *talc,* picrolite, *chromite;* at Carter's chrome mine, brookite.

GAP MINES.—Chalcopyrite, *pyrrhotite* (niccoliferous), *millerite* (botryoidal radiations), *vivianite!* actinolite, *siderite,* hisingerite, pyrite.

PEQUEA VALLEY.—8 m. S. of Lancaster, argentiferous galenite, vauquelinite, rutile at Pequea mine; 4 m. N. W. of Lancaster, *calamite,* galenite, blende; *pyrite* in cubes near Lancaster; at the Lancaster zinc mines, *calamine,* blende, tennantite? *smithsonite* (pseud. of dolomite), *aurichalcite.*

LEBANON CO.—CORNWALL.—*Magnetite, pyrite* (cobaltiferous), chalcopyrite, *native copper, azurite, malachite, chrysocolla, cuprite* (hydrocuprite), *allophane, brochantite,* serpentine, quartz pseudomorphs; *galenite* (with octahedral cleavage), fluorite, covellite, hematite (micaceous), opal, asbestus.

LEHIGH CO.—FRIEDENSVILLE.—At zinc mines, *calamine, smithsonite,* hydrozincite, massive blende, greenockite, quartz, allophane, mountain leather, aragonite, sauconite; near Allentown, magnetite, pipe-iron ore; near Bethlehem, on S. Mountain, allanite, with zircon, magnetite, martite, black spinel, tourmaline, chalcocite.

SHIMERVILLE.—Corundum.

LUZERNE CO.—SCRANTON.—Under peat, phytocollite.

DRIFTON.—Pyrophyllite.

MIFFLIN CO.—Strontianite.

MONROE CO.—In CHERRY VALLEY, *calcite,* chalcedony, quartz; in Poconac Valley, near Judge Mervine's, cryst. quartz.

MONTGOMERY CO.—CONSHOHOCKEN.—Fibrous tourmaline, menaccanite, aventurine quartz, phyllite; in the quarry of Geo. Bullock, *calcite* in hexagonal prisms, aragonite.

LOWER PROVIDENCE.—Perkiomen lead and copper mines, near village of Shannonville, azurite, *blende, galenite,* pyromorphite, cerussite, wulfenite, anglesite, barite, calamine, chalcopyrite, malachite, chrysocolla, *brown spar,* cuprite, covellite (rare), melaconite, libethenite, pseudomalachite.

WHITE MARSH.—D. O. Hitner's iron mine, limonite in geodes and stalactites, *göthite,* pyrolusite, wad, lepidocrocite; at Edge Hill Street, North Pennsylvania Railroad, titanic iron, braunite, pyrolusite; 1 m. S. W. of Hitner's iron mine, *limonite,* turgite, *göthite,* pyrolusite, *velvet manganese,* wad; near Marble Hall, at Hitner's marble quarry, white marble, granular barite, resembling marble; at Spring Mills, limonite, pyrolusite, göthite; at Flat Rock Tunnel, opposite Manayunk, *stilbite, heulandite, chabasite,* ilvaite, beryl, feldspar, mica.

LAFAYETTE, at the Soapstone quarries.—Talc, jefferisite, garnet, albite, serpentine, zoisite, staurolite, chalcopyrite; at Rose's Serpentine quarry, opposite Lafayette, enstatite, serpentine.

NORTHAMPTON CO.—BETHLEHEM.—Axinite, zircon (¾ m. N.).

BUSHKILL T.—Crystal Spring on Blue Mountain, *quartz crystals.*

NAZARETH.—Quartz crystals.

Near EASTON.—*Zircon!* (exhausted), nephrite, coccolite, tremolite, pyroxene, sahlite, limonite, magnetite, purple calcite, bowenite.

WILLIAMS TOWNSHIP.—Pyrolusite in geodes in limonite beds, göthite (lepidocrocite) at Glendon.

NORTHUMBERLAND CO.—Opposite SELIN'S GROVE.—Calamine.

PHILADELPHIA CO.—FRANKFORD.—Titanite in gneiss, apophyllite; at the quarries on Frankford Creek, stilbite, molybdenite, hornblende; on the Connecting Railroad, wad, earthy cobalt; at Chestnut Hill, magnetite, green mica, chalcopyrite, fluorite.

FAIRMOUNT WATER-WORKS.—In quarries opposite Fairmount, *autunite! torbernite,* orthoclase, beryl, tourmaline, albite, wad, menaccanite.

GORGAS'S and CREASE'S LANE.—Tourmaline, cyanite, staurolite, hornstone, fahlunite.

Near GERMANTOWN.—*Black tourmaline,* laumontite, *apatite;* York Road, tourmaline, beryl.

HEFT'S MILL.—Alunogen, tourmaline, cyanite, titanite.

MANAYUNK.—At the soapstone quarries above Manayunk, talc, *steatite,* chlorite, vermiculite, *anthophyllite,* staurolite, dolomite, apatite, asbestus, brown spar, epsomite.

MEAGARGEE'S Paper mill.—Staurolite, titanic iron, hyalite, *apatite,* green mica, iron garnets in abundance.

MCKINNEY'S QUARRY, on Rittenhouse Lane.—Feldspar, *apatite, stilbite,* natrolite, *heulandite,* epidote, hornblende, bornite, malachite.

SCHUYLKILL FALLS.—Chabazite, titanite, fluorite, epidote, muscovite, tourmaline, prochlorite.

SCHUYLKILL CO.—TAMAQUA, near POTTSVILLE, in coal-mines.—*Kaolinite.*

Near MAHANOY CITY.—Pyrophyllite, alunogen, copiapite, in coal-mines.

YORK CO.—Bornite, rutile in slender prisms in granular quartz.

DELAWARE.

NEWCASTLE CO.—BRANDYWINE SPRINGS.—*Fibrolite* abundant, sahlite, pyroxene; Brandywine Hundred, *muscovite,* enclosing reticulated magnetite, *garnet.*

DIXON'S FELDSPAR QUARRIES, 6 m. N. W. of Wilmington (not open).—*Beryl, apatite, cinnamon-stone!* magnesite, serpentine, asbestus, black *tourmaline!* cyanite.

EASTBURN'S LIMESTONE QUARRIES, near the Pennsylvania line.—*Tremolite, bronzite.*

QUARRYVILLE.—Garnet, fibrolite.

Near NEWARK, on the railroad.—Sphærosiderite on drusy quartz, jasper (ferruginous opal), cryst. siderite in cavities of cellular quartz, quartz crystals loose in soil.

WAY'S QUARRY, 2 m. S. of Centreville.—*Feldspar* in cleavage masses, *apatite, mica, dewcylite, granular quartz.*

WILMINGTON.—In Christiana quarries, hypersthene.

KENNETT TURNPIKE, near Centreville.—Cyanite and garnet.

KENT CO.—Near MIDDLETOWN, Polk's marl-pits, *vivianite!*

SUSSEX CO.—Near CAPE HENLOPEN.—Vivianite.

MARYLAND.

BALTIMORE (Jones's Falls, 1¾ mile from B.).—Chabazite (haydenite), heulandite (beaumontite), pyrite, siderite, *mica, stilbite.*

16 m. from Baltimore, on the Gunpowder, *graphite*; 23 m. from B., on the Gunpowder, *talc*; 25 m. from B., on the Gunpowder, *magnetite, sphene,* pycnite; 8 to 20 m. N. of B., in limestone, *tremolite, augite, pyrite,* brown and yellow tourmaline; 15 m. N. of B., *sky-blue chalcedony* in granular limestone; 18 m. N. of B., at Scott's mills, *magnetite,* cyanite.

BARE HILLS.—*Chromite, asbestus, tremolite, talc,* hornblende, *serpentine,* chalcedony, meerschaum, baltimorite, *chalcopyrite,* magnetite, enstatite, bronzite.

CAPE SABLE, near Magothy R.—Amber, pyrite, alum slate.

CARROLL CO.—Near Sykesville, Liberty Mines, gold, magnetite, *pyrite (octahedrons), chalcopyrite,* linnæite (carrollite); at Patapsco Mines, near Finksburg, bornite, *malachite,* siegenite, *linnæite, remingtonite,* magnetite, *chalcopyrite;* at Mineral Hill mine, *bornite,* chalcopyrite, linnæite, gold, magnetite.

CECIL CO., north part.—*Chromite* in serpentine.

COOPTOWN, Hartford Co.—Olive-colored *tourmaline, diallage, talc* of green, blue, and rose colors, *ligniform asbestus, chromite, serpentine.*

DEER CREEK.—*Magnetite!* in chlorite slate.

FREDERICK CO.—Old Liberty mine, near Liberty Town, black copper, malachite, chalcocite, hematite; at Dollyhyde mine, *bornite,* chalcopyrite, pyrite, argentiferous galenite in dolomite.

MONTGOMERY CO.—*Oxide of manganese.*

SOMERSET and WORCESTER COS., N. part.—Bog-ore, *vivianite.*

ST. MARY'S RIVER.—*Gypsum!* in clay.

PYLESVILLE, Hartford Co.—Asbestus mine.

VIRGINIA, WEST VIRGINIA, AND DISTRICT OF COLUMBIA.

ALBEMARLE CO., a little west of the Green Mts.—*Steatite, graphite,* galenite.

AMELIA CO.—Near Court House, *mica! orthoclase, microlite! columbite, orthite,* helvite, *topazolite, amethyst,* fluorite, apatite.

AMHERST CO.—Along the west base of Buffalo Ridge, *copper ores;* on N. W. slope of Friar Mtn., *allanite,* magnetite, zircon.

AUGUSTA CO.—At Weyer's (or Weir's) cave, calcite, stalactites.

BUCKINGHAM CO.—*Gold* at Garnett and Moseley mines, also, pyrite, pyrrhotite, calcite, garnet; at Eldridge mine (now London and Virginia mines) near by, and the Buckingham mines near Maysville, gold, auriferous pyrite, chalcopyrite, tennantite, *barite; cyanite, tourmaline, actinolite.*

CHESTERFIELD Co.—Near this and Richmond Co., bituminous coal, native coke. At Manchester, diamond.

CULPEPPER Co., on Rapidan River.—Gold, pyrite.

FRANKLIN Co.—Grayish steatite.

FAUQUIER Co., Barnett's mills.—Asbestus, gold mines, *barite, calcite.*

FLUVANNA Co.—Gold at Stockton's mine; also tetradymite, at "Tellurium mine."

PHENIX COPPER MINES.—*Chalcopyrite*, etc.

GOOCHLAND Co.—Gold mines (Moss and Busby's).

HARPER'S FERRY, on both sides of the Potomac.—Thuringite (owenite) with quartz.

JEFFERSON Co., at Shepherdstown.—Fluor.

KANAWHA Co.—At Kanawha, *petroleum*, brine springs, cannel coal.

LOUDON Co.—*Tabular quartz, prase, pyrite, talc, chlorite, soapstone*, asbestus, *chromite, actinolite, quartz crystals; micaceous iron*, bornite, malachite, epidote, near Leesburg (Potomac mine).

LOUISA Co.—Walton gold mine, gold, pyrite, chalcopyrite, argentiferous galenite, siderite, blende, anglesite; boulangerite, blende (at Tinder's mine); corundum (40 m. N. of Richmond).

NELSON Co.—Galenite, chalcopyrite, malachite.

ORANGE Co.—Western part, Blue Ridge, hematite; gold at the Orange Grove and Vaucluse gold mines, worked by the "Freehold" and "Liberty" Mining Companies.

ROCKBRIDGE Co.—3 m. S. W. of Lexington.—Barite, *dufrenite*, in bed 10 in. thick, with strengite.

SHENANDOAH Co., near Woodstock.—Fluorite.

SPOTTSYLVANIA Co., 2 m. N. E. of Chancellorsville.—*Cyanite;* gold mines at the junction of the Rappahannock and Rapidan; on the Rappahannock (Marshall mine); Whitehall mine, affording also tetradymite.

STAFFORD Co, 8 or 10 m. from Falmouth.—Micaceous iron, gold, tetradymite, silver, galenite, vivianite.

WASHINGTON Co.—18 m. from Abingdon.—Halite, *gypsum.*

WYTHE Co. (Austin's mines).—*Cerussite, minium, plumbic ochre*, blende, *calamine, galenite*, graphite, aragonite.

On the Potomac, 25 m. N. of Washington.—*Sulphur* in limestone.

NORTH CAROLINA.

ALEXANDER Co.—At Stony Point, *spodumene* var. *hiddenite! beryl! emerald! rutile* (in quartz), *monazite, allanite, quartz, smoky quartz.* At White Plains, *quartz crystals, hiddenite, beryl*, rutile, columbite, tourmaline, scorodite. At Milholland's mill, *rutile, monazite, muscovite*, quartz.

BUNCOMBE Co.—In the mica mines, *muscovite! orthoclase! garnet;* at Swannanda Gap, *corundum* in *cyanite.*

BURKE Co.—Gold, *monazite, zircon*, beryl, *corundum, garnet*, sphene, smoky quartz, *graphite*, iron ores, tetradymite, montanite; in gravels at Brindletown, *octahedrite, brookite, zircon*, fergusonite, *monazite, xenotime* (twinned with zircon), samarskite garnet, tourmaline, magnetite; Linville Mtn., itacolumyte.

CABARRUS CO.—Phenix Mine, gold, barite, *chalcopyrite*, auriferous covellite, pyrite, quartz pseudomorph after barite, tetradymite, montanite; Pioneer mines, *gold*, limonite, pyrolusite, *barnhardtite*, *wolfram*, *scheelite*, cuprotungstite, tungstite, diamond, chrysocolla, chalcocite, molybdenite, *chalcopyrite*, *pyrite*; White mine, needle ore, chalcopyrite, barite; Long and Muse's mine, argentiferous galenite, pyrite, chalcopyrite, limonite; Boger mine, tetradymite; Fink mine, valuable copper ores; McMakin's, tetrahedrite, argentite, barite, magnetite, talc, blende, pyrite, proustite, galenite, pyrolusite; Bangle mine, scheelite.

CALDWELL CO.—Chromite, beryl, *garnet*; near Patterson, *serpentine*.

CATAWBA CO.—*Garnet*, *smoky quartz*.

CHATHAM CO.—Mineral coal, pyrite, chloritoid, bornite, *chalcopyrite*, rutile in quartz, *muscovite*, *pyrophyllite* (slaty).

CHEROKEE CO.—Near Valley River, *tremolite*, *talc* (white steatite), marble of various colors, limonite; *staurolite* (Parker mine).

CLEVELAND CO.—White Plains, *quartz* crystals, *smoky quartz*, tourmaline, rutile in quartz.

CLAY CO.—At the Cullakenee mine and elsewhere, *corundum* (pink), zoisite, tourmaline, margarite, willcoxite, dudleyite, picrolite; Tusquitee Cr., staurolite; at Shooting Creek, chrysolite.

DAVIDSON CO.—King's, now Washington mine, native silver, cerussite, anglesite, scheelite, *pyromorphite*, galenite, blende, malachite, black copper, *wavellite*, garnet, stilbite; 5 m. from Washington mine, on Faust's farm, gold, *tetradymite*, oxide of bismuth and tellurium, montanite, chalcopyrite, limonite, siderite, epidote; near Squire Ward's, gold in crystals, electrum.

FRANKLIN CO.—At Partiss mine, diamond.

GASTON CO.—Iron ores, corundum, margarite; near Crowder's Mountain (in what was formerly Lincoln Co.), *lazulite*, *cyanite*, *garnet*, corundum, *rutile*, margarite, graphite; also 20 m. N. E., near S. end of Clubb's Mountain, lazulite, cyanite, talc, *rutile*, topaz, *pyrophyllite*, corundum; King's Mountain (or Briggs) mine, native tellurium, altaite, nagyagite, tetradymite, montanite, corundum, sphalerite.

GUILFORD CO.—McCulloch copper and gold mine, 12 m. from Greensboro', *gold*, *pyrite*, *chalcopyrite* (worked for copper), *quartz*, siderite; at Deep River, compact *pyrophyllite* (worked for slate-pencils); at Gibsonville, green quartz.

HAYWOOD CO.—*Corundum*, margarite, damourite; Caster mine, *corundum*.

HENDERSON CO.—*Zircon*, sphene (xanthitane).

IREDELL CO.—Statesville, *corundum* enveloped in margarite, quartz crystals, *cyanite*, *actinolite*.

JACKSON CO.—Alunogen? at Smoky Mountain; at Webster, *serpentine*, chromite, genthite, enstatite, *chrysolite*, talc; Hogback Mountain, *pink corundum*, *margarite*, tourmaline.

LINCOLN CO.—Diamond; at Randleman's, *amethyst*, rose quartz, graphite.

MACON CO.—Near Franklin, Culsagee and other mines; *corundum!* spinel, diaspore, chromite, *chrysolite*, talc, enstatite, tremolite, tourmaline, damourite, prochlorite, culsageeite, kerrite, maconite; Jenk's

mine, *corundum!*; Thorn Mtn., beryl; in the mica mines, *biotite* in *muscovite*.

McDOWELL Co.—Brookite, *monazite*, corundum in small red and white crystals, pyrophyllite, *zircons*, garnet, beryl, sphene, xenotime, rutile, iron ores, pyromelane, tetradymite, montanite.

MADISON Co.—20 m. from Asheville, *corundum*, margarite, chlorite; Carter's mine, beryl; staurolite.

MECKLENBURG Co.—Near Charlotte (Rhea and Cathay mines) and elsewhere, *chalcopyrite, gold, zircon*; chalcotrichite at McGinn's mine; barnhardtite near Charlotte; pyrophyllite in Cotton Stone Mountain, diamond; Flowe mine, scheelite, wolframite; Todd's Branch, *monazite*, diamond.

MITCHELL Co.—At the Wiseman mica mine, *muscovite! samarskite!* hatchettolite, euxenite, columbite, rogersite, *uraninite, uranotile, allanite, beryl*, zoisite, garnet, menaccanite, *gummite, uraconite, fergusonite*, torbernite, autunite; at Grassy Creek mine, *muscovite*, beryl, *samarskite*; at Deake mine, gahnite, *mica, monazite! uraninite*, uranotile, gummite, uranochre; near Bakersville, chrysolite.

MONTGOMERY Co.—Steele's mine, Cotton Stone Mtn., ripidolite, albite, *pyrophyllite*.

MOORE Co.—Carbonton, compact *pyrophyllite* (large beds on Linville Mtn.).

ORANGE Co.—At Hillsboro', *pyrophyllite*.

RANDOLPH Co.—At Pilot Knob, pyrophyllite.

ROWAN Co.—Gold Hill mines, 38 m. N. E. of Charlotte, and 14 m. from Salisbury, gold, auriferous pyrite; 10 m. from Salisbury, *feldspar* in crystals, *bismuthinite*.

RUTHERFORD Co.—*Gold, graphite*, bismuthic gold, diamond, euclase, *pseudomorphous quartz?* chalcedony, corundum in small crystals, *epidote, pyrope*, brookite, *zircon*, monazite, rutherfordite, samarskite, *quartz crystals*, itacolumyte; on the road to Cooper's Gap, cyanite.

UNION Co.—Lemmond gold mine, 18 m. from Concord (at Stewart's and Moore's mine), gold, blende, argentiferous galenite, pyrite, chalcopyrite.

WAKE Co.—*Graphite*.

WATAUGA Co.—At Rich Mtn., chrysolite, chromite.

YANCEY Co.—*Iron ores*, amianthus, *chromite, chrysolite*, garnet (spessartite), *cyanite, samarskite, columbite*, corundum, spinel; at Ray mica mine, *muscovite, tantalite* (columbite), *monazite, beryl*, garnet, zircon, rutile; at Hampton's, *chromite, epidote, enstatite*, tremolite, *chrysolite, serpentine, talc, magnesite*.

SOUTH CAROLINA.

ABBEVILLE Co.—Oakland Grove, *gold* (Dorn mine), galenite, pyromorphite, amethyst, garnet.

ANDERSON Co.—At Pendleton, *actinolite*, galenite, kaolin, *tourmaline, zircon*.

CHEOWEE VALLEY.—Galenite, tourmaline, gold.

CHESTERFIELD Co.—Gold (Brewer's mine), talc, chlorite, pyrophyllite, pyrite, native bismuth, bismuth carbonate, red and yellow ochre, whetstone, enargite.

GREENVILLE Co.—Galenite, pyromorphite, kaolin, chalcedony in buhrstone, beryl, plumbago, epidote, *tourmaline.*

KERSHAW Co.—*Rutile.*

LANCASTER Co.—Gold (Hale's mine), talc, chlorite, cyanite, itacolumyte, pyrite; gold also at Blackman's mine, Massey's mine, Ezell's mine.

LAURENS Co.—Corundum, damourite.

NEWBERRY Co.—Leadhillite.

PICKENS Co.—Gold, manganese ores, kaolin.

RICHLAND Co.—Chiastolite, novaculite.

SPARTANBURG Co.—*Magnetite,* chalcedony, *hematite;* at the Cowpens, limonite, *graphite,* limestone, copperas; Morgan mine, leadhillite, pyromorphite, cerussite.

UNION Co.—Fairforest gold-mines, pyrite, chalcopyrite.

YORK Co.—Whetstone, witherite, barite, tetradymite.

GEORGIA.

BURKE AND SCRIVEN COS.—Hyalite.

CHEROKEE Co.—At Canton Mine, chalcopyrite, galenite, clausthalite, plumbogummite, hitchcockite, *arsenopyrite,* lanthanite, *harrisite, cantonite,* pyromorphite, automolite, zinc, staurolite, cyanite: at Ball-Ground, spodumene.

CLARK Co., near Clarksville.—Gold, *xenotime,* zircon, rutile, cyanite, hematite, garnet, quartz.

FANNIN Co.—*Staurolite!* chalcopyrite.

HABERSHAM Co.—*Gold,* pyrite, chalcopyrite, *galenite,* hornblende, garnet, quartz, kaolinite, soapstone, chlorite, *rutile,* iron ores, tourmaline, staurolite, zircon.

HALL Co.—*Gold,* quartz, kaolin, diamond.

HEARD Co.—*Molybdite,* quartz.

LEE Co.—At the Chewacla Lime Quarry, dolomite, barite, *quartz crystals.*

LINCOLN Co.—*Lazulite! rutile!* hematite, cyanite, menaccanite, *pyrophyllite,* gold.

LOWNDES Co.—Corundum.

LUMPKIN Co.—At Field's gold-mine, near Dahlonega, *gold, tetradymite,* pyrrhotite, chlorite, menaccanite, allanite, apatite.

RABUN Co.—Gold, *chalcopyrite, muscovite, beryl, corundum.*

SPAULDING Co.—Tetradymite.

WASHINGTON Co., near Saundersville.—*Wavellite, fire opal.*

WHITE Co.—Racoochee Valley, diamond.

ALABAMA.

BIBB Co., Centreville.—*Iron ores,* marble, *barite,* coal, cobalt.

CHAMBERS Co.—Near La Fayette, *steatite,* garnets, actinolite, *chlorite;* east of Oak Bowery, steatite.

CHILTON Co.—*Muscovite,* graphite, limonite, rutile.

CLEBURNE Co.—At Arbacoochee mine, gold, pyrite, and three miles distant cyanite, garnets; at Wood's mine, *black copper,* azurite, *chalcopyrite,* pyrite.

CLAY CO.—*Steatite*, magnetite; near Delta and Ashland, *muscovite*.

COOSA CO.—Tantalite, gold, muscovite, cassiterite, rutile, mica; near Bradford, zircon, *corundum, asbestus;* near Rockford, *tantalite*.

RANDOLPH CO.—Gold, pyrite, tourmaline, muscovite; at Louina, *porcelain clay*, garnet.

TALLADEGA CO.—*Limonite*.

TALLAPOOSA CO., at Dudleyville.—*Corundum*, margarite, ripidolite, spinel, tourmaline, actinolite, *steatite, asbestus*, chrysolite, damourite, corundum altered to tourmaline (containing a nucleus of corundum), at Dudleyville, dudleyite.

TUSCALOOSA CO.—*Coal*, galenite, pyrite, vivianite, limonite, calcite, dolomite, cyanite, steatite, quartz crystals, manganese ores.

FLORIDA.

NEAR TAMPA BAY.—Limestone, sulphur springs, chalcedony, agate, *silicified shells and corals*.

KENTUCKY.

ANDERSON CO.—Galenite, barite.

CLINTON CO.—Geodes of quartz

CRITTENDEN CO.—Galenite, fluorite, calcite.

CUMBERLAND CO.—At Mammoth Cave, *gypsum rosettes!* calcite, stalactites, nitre, epsomite.

FAYETTE CO.—6 m. N. E. of Lexington, galenite, barite, witherite, blende.

LIVINGSTON CO., near the line of Union Co.—Galenite, chalcopyrite, large vein of fluorite.

MERCER CO.—At McAfee, *fluorite, pyrite*, calcite, barite, celestite.

OWEN CO.—Galenite, barite.

TENNESSEE.

BROWN'S CREEK.—Galenite, blende, barite, celestite.

CLAIBORNE CO.—*Calamite*, galenite, smithsonite, chlorite, steatite, magnetite.

COCKE CO., near Bush Creek.—Cacoxenite? kraurite, iron sinter, stilpnosiderite, brown hematite.

DAVIDSON CO.—Selenite, with granular and snowy *gypsum*, or alabaster, crystallized and compact *anhydrite, fluorite* in crystals? *calcite* in crystals. Near Nashville, blue *celestite* (crystallized, fibrous, and radiated), with *barite* in limestone. Haysboro', galenite, blende, with barite as the gangue of the ore.

DICKSON CO.—Manganite.

JEFFERSON CO.—*Calamine*, galenite, fetid barite.

KNOX CO.—Magnesian limestone, *native iron, variegated marbles!*

MAURY CO.—Wavellite in limestone.

POLK CO., Ducktown mines, S. E. corner of State.—Melaconite, chalcopyrite, pyrite, native copper, bornite, rutile, *zoisite*, galenite, *harrisite*, alisonite, blende, *pyroxene, tremolite, sulphates of copper and iron* in stalactites, allophane, rahtite, chalcocite (ducktownite), chalcotrichite, azurite, malachite, *pyrrhotite*, limonite.

ROAN Co., E. declivity of Cumberland Mts.—Wavellite in limestone.

SEVIER Co., in caverns.—Epsomite, soda alum, nitre, nitrate of calcium, *breccia marble.*

SMITH Co.—Fluorite.

SMOKY MT., on declivity.—Hornblende, garnet, staurolite.

OHIO.

BAINBRIDGE (Copperas Mt , a few miles east of B.).—Calcite, barite, pyrite, copperas, alum.

CANFIELD and POLAND.—*Gypsum!*

LAKE ERIE.—Strontian Island, *celestite!* Put-in-Bay Island, *celestite! sulphur!* calcite.

MICHIGAN.

BREST (Monroe Co.).—*Calcite*, amethystine quartz, apatite, celestite.

GRAND MARAIS.—Thomsonite (lintonite).

GRAND RAPIDS.—*Selenite*, fib. and granular gypsum, *calcite, dolomite, anhydrite.*

LAKE SUPERIOR MINING REGION.—The copper-mines are mostly between Keweenaw Point and Portage Lake. The copper occurs in the trap or amygdaloid, and in the associated conglomerate; and in the latter (which is the rock of the Calumet and Hecla mine) the ore is distributed finely through the mass of the rock. *Native copper! native silver!* chalcopyrite, horn silver, tetrahedrite, manganese ores, epidote, *prehnite, laumontite, datolite*, heulandite, orthoclase, *analcite*, chabazite, compact datolite, chrysocolla, *mesotype* (Copper Falls mine), *leonhardite* (ib.), *analcite* (ib.), *apophyllite* (at Cliff mine), *wollastonite* (ib.), calcite, *quartz* (in crystals at Minnesota mine), compact datolite. orthoclase (Superior mine), *saponite*, melaconite (near Copper Harbor, but exhausted), chrysocolla; on Chocolate River, galenite and sulphide of copper; chalcopyrite and native copper at Presque Isle; at Albion mine, *domeykite;* at Prince Vein, *barite, calcite, amethyst;* at Albany and Boston mine, Portage Lake, *prehnite, analcite, orthoclase*, cuprite; at Sheldon location, *domeykite, whitneyite, algodonite;* Quincy mine, calcite, compact datolite. At the Spur Mountain iron-mine (magnetite), chlorite pseudomorph after garnet; Isle Royale, datolite, prehnite.

MARQUETTE.—Manganite, galenite; 12 m. W., at Jackson Mt., and other mines, *hematite, limonite, göthite!* magnetite, jasper.

MONROE.—Aragonite, apatite.

NEGAUNEE.—*Manganite, göthite, hematite*, barite, kaolinite.

POINT AUX PEAUX (Monroe Co.).—*Amethystine quartz, apatite*, celestite, *calcite.*

SAGINAW BAY.—At Alabaster, *gypsum.*

STONY POINT (Monroe Co.).—Apatite, amethystine quartz, celestite, calcite.

ILLINOIS.

GALLATIN Co., on a branch of Grand Pierre Creek, 16 to 30 m. from Shawneetown, down the Ohio, and from half to eight miles from

this river.—*Violet fluorite!* in Carboniferous limestone, barite, *galenite*, blende, limonite.

HANCOCK CO.—At Warsaw, *quartz geodes* containing *calcite! chalcedony, dolomite, blende!* brown spar, pyrite, aragonite, gypsum, bitumen.

HARDIN CO.—Near Rosiclare, *calcite*, galenite, blende; 5 m. back from Elizabethtown, bog iron; one mile north of the river, between Elizabethtown and Rosiclare, *nitre*.

JO DAVIESS CO.—At Galena, *galenite*, calcite, *pyrite*, blende; at Marsden's diggings, *galenite! blende, cerussite*, marcasite in stalactitic forms, pyrite.

QUINCY.—*Calcite!* pyrite.

SCALES MOUND.—*Barite*, pyrite.

INDIANA.

LIMESTONE CAVERNS; Corydon Caves, etc.—*Epsom salt.*

In most of the southwest counties, *pyrite, iron sulphate*, and *feather alum;* on Sugar Creek, pyrite and *iron sulphate;* in sandstone of Lloyd Co., near the Ohio, *gypsum;* at the top of the blue limestone formation, brown *spar, calcite.*

LAWRENCE CO.—*Kaolinite* (= indianaite), *Allophane*, limonite.

MINNESOTA.

NORTH SHORE OF L. SUPERIOR (range of hills running nearly N. E. and S. W., from Fond du Lac Supérieure to the Kamanistiqueia River on Thunder Bay).—*Scolecite, apophyllite, prehnite, stilbite, laumontite, heulandite, harmotome, thomsonite* (much of it in loose pebbles on shore of L. Sup., between Terrace Point and Poplar River), *fluorite, barite, tourmaline, epidote*, hornblende, calcite, quartz crystals, pyrite, magnetite, steatite, blende, black oxide of copper, malachite, native copper, chalcopyrite, amethystine quartz, *chalcedony, carnelian, agate*, jasper (in the débris of the lake shore), dog-tooth spar, augite, native silver, spodumene? chlorite; near Pigeon Point, graphite, sphalerite, chalcopyrite, barite; between Pigeon Point and Fond du Lac, near Baptism River, saponite (thalite) in amygdaloid; between Split Rock R. and the Great Palisades, anorthite rock; in Mesabi Range, magnetite in beds.

PINE CO.—Kettle River Trap Range. Epidote, nail-head calcite, amethystine quartz, calcite, undetermined zeolites, saponite; also copper ores.

STILLWATER.—Blende.

FALLS OF THE ST. CROIX.—Malachite, native copper, epidote, nail-head spar (calcite).

RAINY LAKE.—Actinolite, tremolite, fibrous hornblende, garnet, pyrite, magnetite, steatite.

WISCONSIN.

BLUE MOUNDS.—Cerussite.

LAC DE FLAMBEAU R.—Garnet, cyanite.

DOUGLAS CO., Left-Hand R. (near small tributary).—Malachite,

chalcocite, native copper, cuprite, malachite, niccolite, tetrahedrite, epidote, chlorite? quartz crystals.

MINERAL POINT and vicinity, in S. W. counties of Wisconsin.—Copper and lead ores, chrysocolla, *azurite!* chalcopyrite, malachite, *galenite*, cerussite, anglesite, blende, *pyrite, barite, calcite, marcasite, smithsonite!* (including pseudomorphs after calcite and blende, so-called "dry-bone"), calamine, bornite, hydrozincite; at Shullsburg, *galenite!* blende, pyrite; at Emmet's digging, *galenite* and pyrite.

MONTREAL RIVER PORTAGE.—Galenite in gneissoid granite.

Penokee and Menominee Iron Ranges S. of L. Superior, *hematite, magnetite, siderite*, actinolite, garnet.

SAUK CO.—Hematite, malachite, chalcopyrite.

IOWA.

DUBUQUE LEAD MINES, and elsewhere.—*Galenite! calcite, blende*, black oxide of manganese, barite, pyrite; at Ewing's and Sherard's diggings, *smithsonite*, calamine; at Des Moines, quartz crystals, selenite; Makoqueta R., limonite; near Durango, galenite; 7 m. S. of Dubuque, aragonite.

CEDAR RIVER, a branch of the Des Moines.—*Selenite* in crystals, in the bituminous shale of the Coal measures; also elsewhere on the Des Moines, gypsum abundant; argillaceous iron ore, siderite.

FORT DODGE.—*Celestite, gypsum*, pyrite.

NEW GALENA.—Octahedral galenite, anglesite.

BENTONSPORT, and elsewhere in Southern Iowa, in geodes.—*Chalcedony, quartz, calcite, dolomite, pyrite*, kaolinite.

MISSOURI.

For the distribution of the lead-mines see page 162. Mine la Motte, and some old openings in Madison Co., afford cobalt and nickel ores abundantly. At Granby and other mines the chief zinc ore is calamine, or the silicate of zinc, while in Central and Southwestern Missouri it is comparatively rare, and smithsonite is the prominent ore, as in Wisconsin: yet calamine is the most abundant zinc ore in the State. As stated by A. Schmidt, the zinc ore is a secondary product to sphalerite (blende); the cerussite often coats the galenite, or has its forms, indicating thus its source; the limonite is also secondary, and has come in mainly through the oxidation of pyrite. At the Granby mines the calamine is called, among the miners, "Black Jack;" blende, "Resin Jack;" a white massive smithsonite, "White Jack;" and the cerussite is the "Dry Bone;" thus departing from ordinary miners' usage. Gold has been found in the drift sands of Northern Missouri (Broadhead).

ADAIR CO.—Göthite in calcite.

COLE CO.—Old Circle Diggings and elsewhere, *barite!* galenite, chalcopyrite, malachite, azurite, pyrite, calcite, calamine, sphalerite.

COOPER CO.—Collin's mine, malachite, azurite, chalcopyrite, *smithsonite, galenite, sphalerite*, limonite.

CRAWFORD CO.—At Scotia iron bed, hematite, amethyst, göthite, malachite.

DADE CO.—Smithsonite.

FRANKLIN Co.—Cove mines, Virginia mines, and mine à Burton, galenite, cerussite, anglesite, barite; at Staton copper-mine, native copper, chalcotrichite, malachite, azurite, chalcopyrite.

IRON Co.—At Pilot Knob and Shepherd Mountain, *hematite*, magnetite, limonite, manganese oxide, bog manganese, serpentine.

JASPER Co. (adjoins S. E. Kansas).—At Joplin mines and Oronogo, *galena! sphalerite*, pyrite, *cerussite*, calamine, dolomite, bitumen.

JEFFERSON Co.—Valle's, *galenite! cerussite*, anglesite, *calamine*, smithsonite, sphalerite, hydrozincite, chalcopyrite, malachite, azurite, pyrite, *barite*, witherite, limonite; Frumet mines, galenite, *barite! smithsonite!* pyrite, limonite.

MADISON Co.—Mine la Motte, *galenite! cerussite! siegenite* (nickel-linnæite), smaltite, *asbolite* (earthy black cobalt ore), bog manganese, *chalcopyrite*, malachite, caledonite, plumbogummite, wolframite. At Enistein silver-mine, *galenite, sphalerite, wolframite, pyrite*, quartz, muscovite, actinolite, fluorite.

MORGAN Co.—Cordray Diggings, *galena*, blende, *barite*.

NEWTON Co. (adjoins S. E. Kansas).—Granby mines, *galenite! cerussite, calamine! sphalerite*, smithsonite, hydrozincite, buratite, greenockite (on sphalerite), pyromorphite, dolomite, calcite, bitumen.

ST. FRANÇOIS Co.—Iron Mountain, hematite, limonite, apatite, tungstite, wolframite, magnetite, menaccanite.

ST. GENEVIÈVE Co.—At copper-mines, *chalcopyrite*, cuprite, malachite, azurite, covellite, chalcocite, bornite, melaconite, chalcanthite.

ST. LOUIS Co.—Near St. Louis, *millerite* (in the Subcarboniferous St. Louis limestone, largely a magnesian limestone) with *calcite!* barite, *fluorite*, anhydrite, gypsum, strontianite.

WASHINGTON Co.—At Potosi, *galenite, cerussite*, anglesite, barite.

ARKANSAS.

BATESVILLE.—In bed of White R., above Batesville, gold.

GREEN Co.—Near Gainesville, lignite.

HOT SPRINGS Co.—At Hot Springs, *wavellite*, thuringite, novaculite; Magnet Cove, *brookite! schorlomite, elæolite*, magnetite, quartz, green coccolite, *garnet*, apatite, *perofskite* (hydrotitanite), *rutile!* ripidolite, thomsonite (ozarkite), *microcline, ægirite*, protovermiculite, variscite.

LAWRENCE Co.—*Smithsonite*, dolomite, galenite; nitre.

MARION Co.—Wood's mine, smithsonite, hydrozincite (marionite) galenite; Poke bayou, *braunite?*

MONTGOMERY Co.—Variscite.

PULASKI Co.—Kellogg mine, 10 m. north of Little Rock, *tetrahedrite, tennantite*, nacrite, galenite, blende, quartz.

SEVIER Co.—Stibnite, stibiconite, bindheimite, jamesonite.

KANSAS.

BROWN Co.—Celestite.

LINN Co., and elsewhere, near Missouri line.—Lead and zinc ores; on Short Creek, *galenite*, cerussite, anglesite, *sphalerite, calamine*.

WALLACE Co., etc.—*Gypsum* in crystals.

DAKOTA.

LAWRENCE Co.—Redwater Valley, *gypsum;* Bear Lodge range, gold.

PENNINGTON Co.—Etta mine, *spodumene! cassiterite, mica, orthoclase, columbite!* leucopyrite, scorodite, olivenite. The Ingersoll claim, 10 m. E. of Harney Peak, *columbite, tantalite,* beryl; Bald Mtn., pitchblende, torbernite or autunite.

MONTANA.

Mountains in which mines occur cover the southwestern part and the western. Commencing on the west:

SILVER BOW Co. (formerly southern part of Deer Lodge Co.).—Summit Valley district, in veins in granite or related rocks (near Butte City), *cerargyrite, argentite, chalcocite, galenite,* silver, gold, malachite, chalcopyrite, bornite, *pyrite,* cerussite, freibergite, sphalerite, manganese ores; Independence distr. and Flint Creek distr. (near Phillipsburg), similar ores with hübnerite.

BEAVER HEAD Co. (S. of Silver Bow Co.)—Near Bannack City, gold and tellurium with pyrite, some galenite, nagyagite; in Bald Mtn. and Trapper districts, ores of lead and copper with silver in limestone.

LEWIS & CLARKE Co.—Silver Creek, in veins in slates and slaty limestones, gold, with some ores of lead and copper and a little silver; at Helena, gold-bearing veins.

JEFFERSON Co.—Gold, aurif. pyrite, some galenite and silver.

MADISON Co.—Silver Star distr., gold in veins in gneiss, some copper and silver ores, manganese ores; Mineral Hill distr. and N. of Virginia City, in gneiss, argentif. galenite, gold; similar ores and rock in Hot Springs and Red Bluff districts.

WYOMING.

ALBANY Co., 14 m. S. W. of Laramie City.—*Thenardite.*

LARAMIE Co.—Near Hartville, chalcocite, chrysocolla, cuprite, malachite; 18 m. E. of Laramie City, graphite.

SWEETWATER Co.—Near Atlantic City, S. Pass City, and Miner's Delight, gold in quartz veins; near Independence Rock, sodium carbonates (trona, etc.).

IDAHO.

ALTURAS Co. (veins mostly in granite).—Middle Boisé, *ruby silver, native silver, gold, cerargyrite, stephanite,* argent galenite, argentite, *pyrite,* chalcopyrite, *freibergite,* arsenopyrite, sphalerite; Hardscrabble, gold, pyrite, arsenopyrite. Other mines at Bonaparte (gold and silver ores), Mineral Hill (silver ores), Queen's River (gold and silver ores), Red Warrior (gold and silver ores), Rocky Bar (gold), Sawtooth (silver ores); at Jay Gould mine, with the other ores, *native lead.*

BOISÉ Co. (veins in granite).—Banner, ruby silver ore, cerargyrite, pyrite; gold at Cañon Creek, Gambrinus, Granite, Shaw's Mountain, etc.

IDAHO CO.—Warren's Camp (veins in slate and limestone), gold, silver, cerargyrite, etc., scheelite with gold (Charity mine).

LEMHI CO.—Bay Horse (veins in slate), *argent. galenite, chalcocite,* cerargyrite, bromyrite, malachite, gold; Yankee Fork, gold, pyrite, chalcopyrite, stephanite?

OWHYHEE CO.—(Veins in granite, metamorphic, and other rocks intersected by dikes of igneous rocks, situated near Silver City, on the Jordan R.) Carson, gold, silver, cerargyrite, etc.; Wagontown, gold, argentite, pyrite, stephanite; on Jordan R., stream tin. Gold also in Oneida Co., at Cariboo and Iowa Bar, Kootenai, Nez Percé, Shoshone and Washington Cos.; Bear Lake Co. (S. E. corner of Idaho), near Soda Spring, soda carbonate, salt, sulphur.

COLORADO.

BOULDER CO. (eastern part, between Jamestown and Magnolia, noted for rich tellurides with tellurium).—Central distr. (Smuggler mine, etc., in mica schist or gneiss); tellurides, pyrite; Gold Hill distr. (Red Cloud, etc., mines), gold, tellurides of gold, silver, mercury, pyrite, sphalerite, chalcopyrite; Magnolia distr., tellurides, etc., tellurium ores of the range including *altaite, hessite, petzite, sylvanite, tellurite, native tellurium, calaverite, coloradoite, melonite, ferro-tellurite, magnolite,* and the associated ores, argentite, amalgam, native mercury, native bismuth, bismuthinite, bismutite, pyrargyrite, iodyrite, kobellite, *schirmerite,* hübnerite; Sunshine and Sugar Loaf districts afford tellurides; Ward distr., aurif. pyrite and chalcopyrite, gold; Grand Island distr. (Caribou mine), *argentif. galenite,* chalcopyrite, pyrite, gold, sphalerite; Sugar-Loaf distr., chalcocite, pyrrhotite, manganesian garnet.

CHAFFEE CO.—Arrow mine, jarosite with turgite; gold gravels (at Cash Creek, etc.); Monarch distr., cerussite, brochantite, etc.; near Mt. Anteros, in Arkansas Valley, *beryls;* at Salida, *garnets;* at Nathrop, in cavities in rhyolyte, *topaz, garnet.*

CLEAR CREEK CO.—Georgetown, argentif. *galenite, native silver, pyrargyrite,* argentite, tetrahedrite, pyromorphite, sphalerite, azurite, aragonite, barite, fluorite, polybasite (Terrible Lode), mica; Trail Creek, garnet, epidote; Freeland Lode, *tetrahedrite,* tennantite, anglesite, caledonite, cerussite, tenorite, siderite, azurite, minium; Champion Lode, tenorite, azurite, chrysocolla, malachite; Gold Belt Lode, vivianite; Coyote Lode, malachite, cyanotrichite; Virginia district, galenite, chalcopyrite, pyrite, tetrahedrite.

CUSTER CO.—Near Rosita and Silver Cliff, 6 m. W. of R., argent. galenite, sphalerite, pyrite, chalcopyrite, annabergite, carrying silver and gold, ores at the latter place incrusting fragments or pebbles of country rock, *calamine, smithsonite, jamesonite, tetrahedrite,* tellurites of silver and gold, *niccolite;* also at the Racine Boy mine, cerussite, cerargyrite; at the Gem mine, 12 m. N. of Silver Cliff, niccolite, bornite, pyrite; E. slope of Sangre de Cristo, Verde mine, *chalcopyrite, tetrahedrite,* pyrite.

EL PASO CO. (includes, in W. part, Pike's Peak).—25 m. N. of Pike's Peak, near Platte (Devil's Head) Mtn., *topaz! microcline, albite, phenacite, smoky quartz, göthite,* fluorite, cassiterite, allanite, gadolin-

ite; near Florissant, 12 m. N. W. from the Peak, *microcline! topaz!* on Elk Creek, phenacite, microcline (*amazon stone*), *smoky quartz! amethyst! albite, fluorite, zircon! columbite!*; south of Manitou, in Crystal Park, *topaz, phenacite*, zircon. Near Pike's Peak toll-road, W. of Cheyenne, N. E. base of St. Peter's Dome, in quartz vein, *zircon, astrophyllite, arfvedsonite, cryolite, thomsenolite*, gearksutite, prosopite, ralstonite, elpasolite, tysonite, bastnæsite; in another vein, *prosopite*, zircon, fluorite, kaolinite, yellowish mica, cryolite; between Colorado Springs and Cañon City, barite; Garden of the Gods, celestite, rhodochrosite.

GILPIN Co.—Veins in gneiss or granite. Near Central City, Gregory dist., about Black Hawk (Bobtail mine, etc.), chalcopyrite, pyrite, sphalerite, galenite, *enargite* and fluorite; in Willis Gulch, uraninite (Wood mine); Nevada district (next west of Gilpin), galenite, chalcopyrite, pyrite, sphalerite, etc.; Russell dist. (in Russell Gulch), *galenite*, tetrahedrite, *enargite*, pyrite, *fluorite, chalcopyrite*, pyrite, epidote.

GUNNISON Co. (W. of Sawatch Mts. and S. of Elk Mts.).—Ruby district, ruby silver, arsenopyrite, in quartz vein; on Brush Creek, W. base of Teocalli Mtn., nickeliferous *löllingite, smaltite*, marcasite, *native silver*, proustite, pyrargyrite, argentite, galenite, chalcopyrite, in a gangue of siderite, barite, and calcite.

HINSDALE Co.—Lake City, Hotchkiss Lode, *petzite*, calaverite; Lake district, argent. *galenite, freibergite, sphalerite*, aurif. chalcopyrite, argentobismutite; Park district, *stephanite, galenite*, chalcopyrite; Galena district, argent. galenite, freibergite, sphalerite, chalcopyrite, *rhodocrosite*, stephanite, ruby silver, gold, silver.

HUERFANO Co.—Southern border, N. slope, W. Spanish Peaks, galenite, pyrite, chalcopyrite, tetrahedrite.

JEFFERSON Co.—Near Golden, on Table Mtn., leucite, *analcite, apophyllite, chabazite*, levynite, laumontite, mesolite, natrolite, scolecite, stilbite, thomsonite, calcite, aragonite; Turkey Creek, columbite.

LAKE Co. (between Mosquito Mts. and Sawach Range, both Archæan at centre), supplying three fourths of the silver and gold of Colorado, with Paleozoic rocks between, and great eruptive formations.—About Leadville (or California mining district), on W. portion of Mosquito Range, and mostly confined to Lower Carbonif. limestone, and generally beneath eruptive rocks, *silver, galenite, cerussite, anglesite, cerargyrite, bromyrite*, iodyrite, *embolite, aurif. chalcopyrite* and *pyrite, sphalerite, pyromorphite*, minium, pyrolusite, *rhodochrosite*, calamine, sphalerite, bismuthinite, bismutite, gold, dechenite (in Morning Star and Evening Star mines), kobellite (Printer Boy hill); Florence mine, bismutite; Ute and Ule mines, *stephanite, galenite, sphalerite, chalcocite*; Homestake Peak, N. W. corner of county, *argent. galenite*; Golden Queen mine, *scheelite, gold.*

LA PLATA Co. (S. of San Juan Co.).—S. side of La Plata Mts., 2½ m. N. of Parrott City, *aurif. pyrite*, galenite, tetrahedrite, cosalite (Comstock mine).

OURAY Co. (W. of N. end of Hinsdale Co., with Uncompaghgré Mts. between).—Near Ouray, *argent. galenite*, some *freibergite, chalcopyrite, pyrite, hübnerite*, rhodochrosite; at National Bell mine, *kaolinite* in cryst.

PARK CO.—Mines chiefly along its northwest side, on the E. slope of the Mosquito range, in the Paleozoic region of its eastern side, near eruptive rocks. In N. part Hall's Valley, veins in gneiss, galenite, tetrahedrite, enargite, pyrite, sphalerite, fluorite, barite, ilesite; near Grant, Baltic Lode, begeerite, N. W. of Alma, on Mts. Bross and Mt. Lincoln, in Carbonif. limestone, *argent. galenite, cerussite, anglesite, cerargyrite, barite,* manganese oxide; in Buckskin Gulch (between these mts.), in Cambrian quartzyte, aurif. pyrites, gold, silver, galenite; Sweet Home and Tanner Boy mines, S. W. side of Mt. Bross, in Archæan, *rhodochrosite* in the latter; in Mosquito Gulch, south of Alma, near Horseshoe, *argent. galenite, cerussite.* Mines of Lincoln Mtn. at 13,000 to 14,000 ft. elevation.

PITKIN CO. (between Elk Mts. and Sawatch Range).—At Independence, on W. slope of Sawatch, on the Roaring Fork, in Archæan, and west of Aspen, on the N. E. slope of Elk Mts., Alpine Pass, Pitkin and Tin Cup mines, in limestone, cerussite, cerargyrite, cuprite.

RIO GRANDE CO.—At head of Rio Alamosa, near Summitville, E. part of San Juan Mts., *gold,* in quartz veins, enargite.

SAN JUAN CO. (S. and S. E. of E. end of San Miguel Co., crossed by the San Juan Mts.).—Animas and Eureka districts, about Baker's Park and Silverton, freibergite, argent. galenite, cerussite, azurite, malachite, chalcopyrite, chalcocite, covellite, barite, *zunyite,* and *guitermanite* (at Zuñi mine); Red Mtn. dist. (Brobdignag mine), *zinkenite,* enargite, tennantite, hübnerite (Adams' mine); Poughkeepsie Gulch, Alaska mine, alaskaite, chalcopyrite, tetrahedrite, barite, tellurite; Yankee Girl mine, cosalite.

SAN MIGUEL CO. (S. of Ouray Co., eastern part including N. portion of San Juan Mts.).—At Sneffels (near Mt. Sneffels), freibergite, stephanite, argent. galenite, cerussite, etc.; Upper San Miguel and Iron Springs districts, similar ores; at Telluride, galena, stephanite, chalcopyrite, gold, electrum.

SUMMIT CO.—In southeastern part, on W. slope of Archæan "Front Range," near Montezuma and Peru, argent. galenite, etc.; in southern part, near headwater of Blue R., S. of Breckenridge, near Robinson, on Quandary Peak, etc., in limestone, *argent. galenite, pyrite,* native gold, sphalerite; Chalk Mtn., junction of Summit Park and Eagle Cos., in rhyolyte (nevadite), *sanidin, topaz* in small crystals; Snake River district, alabandite (Queen of the West mine), with rhodocrosite.

UTAH.

The silver-mines are mostly in limestone, with eruptive rocks in the vicinity, and argentif. galenite, cerussite, anglesite, cerargyrite, etc., the common ores. The veins in slate or quartzyte in part carry copper ores. There are also, as shown first by Prof. Newberry, sandstones in Southern Utah impregnated by ores (cerargyrite, etc.) over large regions.

BEAVER CO.—Bradshaw, cerussite, cuprite, malachite, aragonite; San Francisco, cerussite, anglesite, galenite, dufrenoysite, proustite, pyrargyrite, cerargyrite, argentite, barite; Star, cerussite, cerargyrite, malachite.

IRON Co.—Coyote district, orpiment, realgar, thin layer in strata under lava.

JUAB Co.—Tintic district, *galenite, anglesite, cerussite,* malachite, bornite, cuprite, *bismuthite, olivenite, conichalcite, chenevixite, jarosite,* calcium arsenate (at American Eagle mine); *enargite* (at Mammoth, Shoebridge, and Dragon mines); 40 m. N. of Sevier Lake and 40 m. W. N. W. of Deseret, *topaz* in rhyolyte, with garnet and sanidin.

PIUTE Co.—Ohio, *galenite, cerussite,* malachite, chalcopyrite, chalcocite, tetrahedrite; Mt. Baldy, *galenite, cerussite, anglesite, wulfenite,* argentite (Pluto mine); Marysvale, onofrite. Tiemannite (at Lucky Boy mine).

SALT LAKE Co.—Big Cottonwood, *galenite, cerussite, anglesite,* malachite, with sometimes pyrolusite; Little Cottonwood, at Emma and other mines, same, with sometimes argentite, *dufrenoysite, wulfenite,* linarite, chalcopyrite, enargite (at Oxford and Geneva mine); West Mountain, same ores, with argentite, pyrargyrite, rhodochrosite, barite at Queen mine; binnite, etc., at Tiewaukee mine; dufrenoysite, etc., at Winnamuck mine; Butterfield Cañon, orpiment, realgar, mallardite, luckite; Wasatch Mts., head-waters of Spanish Fork, ozocerite in beds.

SUMMIT Co.—Uintah, *cerussite, anglesite, cerargyrite, tetrahedrite, argentite,* malachite.

TOOELE Co.—Camp Floyd, stibnite, etc.; Ophir, *galenite, cerussite, malachite, chalcopyrite, cerargyrite;* Rush Valley, same ores: American Fork and Silver Lake, same ores.

WASATCH Co.—Blue Ledge and Snake Creek, galenite, cerussite, pyromorphite, sphalerite, etc.

WASHINGTON Co.—Harrisburg, in sandstone and clay, *native silver, cerargyrite, argentite;* fossil plants sometimes replaced by silver and cerargyrite.

NEW MEXICO.

DOÑA ANA Co.—At Lake Valley, in the Sierra mines, in limestone, *argent. galenite, cerussite, cerargyrite, embolite,* iodyrite, manganese ores, vanadinite, *endlichite, descloizite,* native silver, pyrolusite, manganite, fluorite, apatite: Victoria mine, 40 m. below Nutt, *anglesite;* at Kingston, in Black Range, aragonite.

Grant Co.—S. W. corner of N. Mexico, adjoining Arizona.—In N. E. corner of county, S. part of Mimbres Mtn., E. of Silver City, ores in limestone or shale, argentif. galenite, cerargyrite, argentite, native silver, barite, fluorite; Santa Rita mines, in porphyry near limestone, native copper, tenorite; Pinos Altos Mtn., N. of Silver City, argent. galenite, cerargyrite, cerussite, argentite, silver, gold, chalcopyrite, barite; Burro Mts., S. W. of Silver City, similar ores; in S. W. part of Co., near Barney's Station and Warren, Virginia distr., veins of quartz, with argent. galenite, cerargyrite, native silver.

SANTA FÉ Co.—Los Cerillos dist., 22 m. S. W. of Santa Fé, in L. C. Mts., *turquois* in trachyte, argent. galenite, cerussite, wulfenite, manganese ores; Silver Bute distr., in quartzyte, gold, pyrite, azurite, malachite, cuprite, chalcopyrite, bournonite, chrysocolla.

SIERRA CO. (S. of Socorro Co.).—Near Hillsboro', gold in veins and placers.

SOCORRO CO. (N. E. of Grant).—3 m. from Socorro, in Socorro Mts., *cerargyrite, vanadinite,* vanadiferous mimetite, *barite;* in Magdalena Mts., 27 m. W. of Socorro, galenite, cerussite, anglesite, calamine, sphalerite; Oscuro Mts. to E., chalcopyrite, azurite, malachite, associated with fossil wood and plants; at Grafton, gold, cerussite, chalcocite, bornite, malachite, chalcopyrite, cerargyrite, amethyst.

ARIZONA.

APACHE CO.—Copper Mountain, chalcocite, azurite, melaconite, sphalerite, pyrite; and at Greenlee Gold Mountain, chalcocite, malachite, cuprite, auriferous gravel.

COCHISE CO. (S. E. corner of State).—20 m. from Tombstone, *turquois* (chalchuite); Bisbee, *malachite, aurichalcite.*

GRAHAM CO.—Clifton, dioptase, cuprite, *azurite,* chrysocolla.

MARICOPA CO.—Vulture district (and on borders of Yavapai Co.), at Farley's Collateral mines (20 m. N. of V.), *vanadinite,* chrysocolla, *crocoite,* descloizite, gold; at Phenix and other mines near the last, *vanadinite,* gold, *vauquelinite, crocoite,* phœnicochroite, silver, sphalerite, argentite, pyrargyrite; Tip Top (at Humbug, in Yavapai Co.), east of last, *silver, sphalerite, argentite, pyrargyrite;* 2½ m. S. W. of Fort Verde, large bed of *thenardite;* Globe district (partly in Pinal Co.), *argentite,* stromeyerite, bornite, chalcopyrite, chalcocite, malachite, cuprite, manganese ore, barite; Jerome, gerhardtite.

MOHAVE CO. (veins in granitoid rocks).—Hualapai district, *galenite, cerussite, sphalerite, ruby silvers,* chalcopyrite, *pyrite;* Maynard, *galenite, stephanite, argentite, silver,* gold. *cerargyrite, sphalerite;* Cedar Valley district (Congress and other mines), *galenite, ruby silvers, tetrahedrite, cerargyrite,* sphalerite, pyrite; Owens district (Signal mine, etc.), *galenite, argentite,* etc.

PIMA CO.—Many of the veins in limestone, which is probably Carboniferous, near eruptive rocks, and others in granite; Oro Blanco, near Mexican line, argentif. *galenite, cerussite, malachite, cerargyrite, freibergite,* etc.; Arivaca, Tubac, similar ores; Tombstone, *galenite, cerargyrite, silver, gold, cerussite,* malachite, pyrolusite; similar ores at Hartford, Meyers, etc.; near Tucson, copper ores; Turquois (western part of county, Ajo mine in quartzyte), chalcopyrite, bornite, malachite; and Defiance mine in limestone, argent. galenite, cerussite.

PINAL CO.—Globe (Stonewall Jackson, etc., mines). See MARICOPA CO.—Pioneer (Silver King, El Capitan, and other mines), *silver, freibergite,* argentite, *stephanite,* stromeyerite, *chalcopyrite,* bornite, malachite, azurite, galena, sphalerite, pyrite, polybasite, miargyrite, pyrargyrite (last three from El Capitan); *vanadinite* and wulfenite (Black Prince mine, Pioneer distr.).

YAVAPAI CO.—Big Bug (Silver Belt mine, in gneiss or granite), *galenite, cerussite, cerargyrite, barite, calcite;* Jerome, gerhardtite. See further, MARICOPA CO.

YUMA CO.—Castle Dome, in gneiss, *argent. galenite, anglesite, cerussite, fluorite, vanadinite, wulfenite, mimetite;* Silver district (veins in gneiss and mica slate, Hamburg, Princess, Red Cloud, etc., mines), *argent. galenite, anglesite, cerussite, wulfenite, vanadinite,* fluorite.

NEVADA.

The chief mining regions of Nevada affording silver and partly gold are either veins connected obviously with igneous eruptions, as the Comstock Lode; veins in granitic or metamorphic rocks, as the Austin mines; and deposits or supposed veins in limestone, either of the Cambrian or later age, as the Eureka and White Pine mines.

CHURCHILL Co.—Ragtown, *gay-lussite, trona,* halite; Cottonwood Campus, *niccolite, annabergite.*

ELKO Co.—Tuscarora, veins in igneous rocks, *stephanite, cerargyrite, ruby-silver ores* (proustite and pyrargyrite), *argentite, stephanite, chalcopyrite,* pyrite, sphalerite, chrysocolla.

ESMERALDA Co.—In metamorphic slates and schists, or in granite, which are intersected by igneous rocks, at Columbus, gold, *cerargyrite, tetrahedrite,* galenite, pyrite, sphalerite, pyrolusite, turquois, stetefeldite; also gold in Esmeralda and Wilson in quartz; silver, galenite, and chalcopyrite in Oneota, in mica schist; Alum, 12 m. N. of Silver Creek; at Aurora, fluorite, stibnite; near Mono Lake, native copper and cuprite, obsidian; Thiel Salt Marsh, *ulexite, borax,* common salt, *thenardite;* Columbus district, *ulexite, thenardite,* sulphur; Walker Lake, gypsum, hematite.

EUREKA Co.—Eureka, Ruby Hill, etc., in Lower Cambrian limestone, *gold, silver, cerussite, galenite, anglesite,* mimetite, *wulfenite,* limonite, aragonite; at Cortez, *cerargyrite, tetrahedrite,* silver, etc.

HUMBOLDT Co.—Veins in Mesozoic slates, at Paradise; *silver, cerargyrite, tetrahedrite, pyrargyrite,* proustite, *stephanite,* arsenopyrite, chalcopyrite, sphalerite, pyrite; between slate and granite at Winnemucca, sulphides and antimonial sulphides of lead, with silver, jamesonite, stibnite, bournonite; near Lovelock's Station, erythrite, millerite, asbolite.

LANDER Co.—At Austin, near Reese River, in the Toyabe Range, which has a granitic axis flanked by Paleozoic strata, and the veins in the granite of Lander Hill (yielding $1,000,000 of silver annually), situated near the western edge of the Paleozoic area of the eastern half of the Great Basin, *tetrahedrite, pyrargyrite, proustite, cerargyrite, stephanite, polybasite,* rhodochrosite, embolite, chalcopyrite, pyrite, galenite, azurite, whitneyite; also mines at Lewis of ruby silver, etc., in quartzyte; and at Battle Mountain, of galenite in Paleozoic slate.

LINCOLN Co.—Bristol, galenite, cerussite, etc.; Eldorado, *cerargyrite, stromeyerite;* Jack-Rabbit, *argentif. galenite, cerussite,* cuprite, malachite; Ely, gold, *cerargyrite, galenite,* sphalerite, pyrite.

NYE Co.—At Belmont (vein in Silurian slate), *argent. galenite, stephanite,* pyrite, chalcopyrite, *anglesite, stetefeldite;* Morey, *ruby silver* and other arsenical and antimonial ores, etc.; Tybo, *galenite, cerargyrite,* etc.; Union, *cerargyrite,* galenite, sphalerite, etc.; Downieville, anglesite, cerussite, wulfenite, sphalerite, pyrite.

STOREY and LYON Cos.—Mines of the Comstock Lode, gold, *native silver, argentite, stephanite, polybasite, ruby silver ores,* tetrahedrite, cerussite, wulfenite, küstelite, etc.

WHITE PINE Co.—White Pine, in Devonian limestone, cerargyrite; at Ward, same limestone, sulphantimonides (probably stromeyerite), pyrite, etc.; at Cherry Creek, copper carbonate, sulphides, etc.

CALIFORNIA.

The principal *gold* regions are in Fresno, Mariposa, Tuolumne, Calaveras, El Dorado, Placer, Nevada, Yuba, Sierra, Butte, Plumas, Shasta, Siskiyou, and Del Norte counties, although gold is found in almost every county of the State.

The *copper-mines* are principally at or near Copperopolis, in Calaveras County; near Genesee Valley, in Plumas County; near Low Divide, in Del Norte County; on the north fork of Smith's River; at Soledad, in Los Angeles County.

The *mercury-mines* are at or near New Almaden and North Almaden, in Santa Clara County; at New Idria and San Carlos, Monterey County; in San Luis Obispo County; at Pioneer mine, and other localities in Lake County; in Santa Barbara County.

ALAMEDA Co.—Diabolo Range, magnesite.

ALPINE Co.—Morning Star mine, *enargite*, stephanite, polybasite, barite, quartz, pyrite, tetrahedrite, pyrargyrite.

AMADOR Co.—At Volcano, chalcedony, *hyalite;* Ione Valley, chalcopyrite, ionite, lignite; Fiddletown, diamond; gold at several mines with chalcopyrite, pyrite, galenite.

BERNARDINO Co.—At Borax works, *hanksite!*

BUTTE Co.—Cherokee Flat, *diamond*, platinum, iridosmine, chromite, zircon.

CALAVERAS Co.—Copperopolis, and Campo Seco, *chalcopyrite*, malachite, *azurite, serpentine, picrolite*, native copper; near Murphy's, jasper, opal; albite, with gold and pyrite; Mellones mine, *calaverite, petzite.*

COLUSE Co.—Butte City, Gagnon mines, goslarite, wurtzite.

DEL NORTE Co.—Crescent City, agate, carnelian; Low Divide, chalcopyrite, bornite, malachite; on the coast, iridosmine, platinum, gold in gravel, zircon, diamond.

EL DORADO Co.—Pilot Hill, chalcopyrite; near Georgetown, hessite, from placer diggings; Roger's Claim, Hope Valley, *grossular garnet*, in copper ore; Coloma, *chromite;* Placerville, *gold;* Granite Creek, roscoelite, gold; Forest Hill, diamond; Cosumnes mine, molybdenite.

FRESNO Co.—Chowchillas, *andalusite;* King's River, bornite; New Idria, cinnabar.

HUMBOLDT Co.—Cryptomorphite.

INYO Co.—Inyo district, *galenite, cerussite, anglesite, barite*, atacamite, calcite, *grossular garnet!* vesuvianite, datolite; Panamint, tetrahedrite, stromeyerite; Kearsarge mine, cerussite, tetrahedrite, cerargyrite, argentite; Cerro Gordo, wulfenite, cerussite, anglesite, polybasite.

KERN Co.—Green Monster mine, cuproscheelite.

LAKE Co.—Borax Lake, *borax!* sassolite, *glauberite;* Pioneer mine, cinnabar, native mercury, selenide of mercury; near the Geysers, sulphur, hyalite, cinnabar; Lower Lake, chromite.

LOS ANGELES Co.—Near Santa Anna River, *anhydrite;* Williams Pass, chalcedony; Soledad mines, chalcopyrite, *garnet*, gypsum; Mountain Meadows, garnet, in copper ore; at Brea Branch, vivianite nodules with asphaltum; at Compton, Kelsey mine, erythrite.

MARIPOSA Co.—Chalcopyrite, itacolumyte; Centreville, cinnabar;

Pine Tree mine, tetrahedrite; Burns Creek, limonite; Geyer Gulch, pyrophyllite; La Victoria mine, *azurite!* near Coulterville, *cinnabar, gold.*

Mono Co.—At Blind Spring, Partzite (stibiconite), chalcocite, chalcopyrite, tetrahedrite; at Bodie, gold, silver; at Iridian, tetrahedrite, sphalerite, galenite, silver.

Monterey Co.—Alisal mine, arsenic; near Paneches, chalcedony; New Idria mine, *cinnabar;* near New Idria, chromite, zaratite, chrome garnet; near Pacheco's Pass, stibnite.

Napa Co.—Chromite; at Cat Hill, Redington mine, *cinnabar, metacinnabarite,* marcasite, bitumen.

Nevada Co.—Grass Valley, *gold!* in quartz veins, with pyrite, chalcopyrite, blende, arsenopyrite, galenite, *quartz,* biotite; near Truckee Pass, gypsum; Excelsior Mine, molybdenite, with gold; Sweet Land, pyrolusite.

Placer Co.—Miner's Ravine, *epidote!* with *quartz, gold.*

Plumas Co.—At Cherokee, chalcopyrite.

Santa Barbara Co.—San Amedio Cañon, stibnite, asphaltum, bitumen, maltha, petroleum, cinnabar, iodide of mercury; Santa Clara River, sulphur.

San Bernardino Co.—Colorado River, agate, trona; at Clarke and Silver Mountain, stromeyerite, malachite; at Temescal Mts., cassiterite; Russ District, galenite, cerussite; Francis mine, cerargyrite; Slate Range, thenardite, borax, common salt, hanksite; San Bernardino Mts., graphite.

Santa Clara Co.—New Almaden, *cinnabar,* mercury, *calcite, aragonite,* serpentine, chrysolite, quartz, aragotite; North Almaden, chromite; Mt. Diabolo Range, magnesite, datolite, with vesuvianite and garnet.

San Francisco Co.—Red Island, pyrolusite and manganese ores.

San Luis Obispo Co.—Asphaltum, cinnabar, native mercury, chromite.

Sierra Co.—Forest City, gold, arsenopyrite, tellurides.

Sonoma Co.—At Guerneville, actinolite, garnets, chromite, serpentine, cinnabar, bitumen.

Trinity Co.—At Cinnabar, cinnabar, serpentine.

Tuolumne Co.—Tourmaline, tremolite; Sonora, *graphite,* gold, chalcopyrite, pyrite; York Tent, chromite; Golden Rule mine, petzite, calaverite, altaite, hessite, magnesite, tetrahedrite, gold; Whiskey Hill, *gold!*

LOWER CALIFORNIA.

La Paz, cuproscheelite. Loretto, natrolite, siderite, selenite. Volcano of Cerro de las Virgines, leucite.

OREGON.

Gold is obtained west of the Cascade Range, in the southernmost counties, Josephine, Jackson, and Curry, in Coos and Douglass, the next north, and east of the range, in southeastern Oregon, in Grant and Baker counties, and to the north sparingly in Wasco,

Umatilla, and Union counties. The most productive mines are in Baker Co.

BAKER CO.—In northern part, about Baker City, Rye Valley, Bridgeport on Burnt River, Willow Creek, Silver Creek, gold; Rye Valley and Silver Creek affording also stromeyerite, arsenopyrite, pyrite, malachite, azurite.

CURRY CO.—Near Port Orford and Cape Blanco, and on the Rogue River, gold, platinum, iridosmine, laurite. On the seashore, 5 m. N. of Chetko, *priceite*, in veins and in masses from 20 lbs. weight to the size of peas and smaller, with bluish steatite.

DOUGLASS CO.—New Idrian, cinnabar, limonite; in Piney Mtn., hydrous nickel silicate.

GRANT CO.—Granite, in north part of county, tetrahedrite, polybasite, chalcopyrite, pyrite, sphalerite. At Elk Creek, auriferous gravel; near Canyon City (on John Day's R.) cinnabar.

JACKSON CO.—At Applegate and elsewhere, auriferous gravel.

JOSEPHINE CO.—Auriferous gravel; at Yank, galenite, chalcopyrite.

WASCO CO.—At Ochoco, auriferous gravel.

WASHINGTON.

KING CO.—Seattle, scheelite, tourmaline; magnetite at Iron Mt., 3 m. N. W. of Snoqualmie Pass, and also copper ores at the Denny Co. mine.

STEVENS CO.—Colville district mines of lead and silver reported.

WHATCOM CO.—Fidalgo, tourmaline.

YAKIMA CO.—Auriferous gravel and quartz veins.

DOMINION OF CANADA.

PROVINCE OF QUEBEC.

ABERCROMBIE.—Labradorite.

ALDFIELD, Pontiac Co.—*Molybdenite!!*

ALLEYN TOWNSHIP, Pontiac Co.—Molybdenite, *molybdite.*

AUBERT.—Gold, iridosmine, platinum.

BAIE ST. PAUL.—*Menaccanite!* apatite, allanite, rutile.

BOLTON.—*Chromite, magnesite,* serpentine, picrolite, *steatite,* bitter spar, wad, rutile.

BOUCHERVILLE.—*Augite* in trap.

BRASSARD, Berthier Co.—Samarskite.

BROME.—*Magnetite,* chalcopyrite, *sphene,* menaccanite, phyllite, sodalite, cancrinite, galenite, chloritoid, rutile.

BROUGHTON.—Serpentine, *chrysotile,* steatite.

BUCKINGHAM TOWNSHIP, Ottawa County.—Apatite and various associated minerals.

CHAMBLY.—Analcite, chabazite and calcite in trachyte, *menaccanite.*

CHATEAU RICHER.—*Labradorite, hypersthene,* andesite.

DAILLEBOUT.—Blue spinel with clintonite.

GRENVILLE.—Wollastonite, *sphene*, *muscovite*, vesuvianite, calcite, pyroxene, serpentine, steatite (rensselaerite), chondrodite, *garnet* (cinnamon-stone), *zircon*, *graphite*, *scapolite*.

FITZROY.—Graphite.

HAM.—Chromite in serpentine, diallage, *antimony! senarmontite! kermesite! valentinite*, stibnite.

HULL TOWNSHIP, Ottawa County.—Apatite, hornblende, titanite, tourmaline, barite, fluorite, jasper (Chelsea).

HUNTERSTOWN.—*Scapolite*, *sphene*, vesuvianite, garnet, *brown tourmaline!*

INVERNESS.—Bornite, chalcocite, pyrite.

JONQUIÈRE TOWNSHIP.—*Beryl.*

LAKE ST. FRANCIS.—*Andalusite* in mica schist.

LEEDS.—Dolomite, chalcopyrite, gold, *chloritoid*, chalcocite, bornite, pyrite, *steatite*.

MAISONNEUVE TOWNSHIP, Berthier County.—*Samarskite*, beryl, muscovite.

MILLE ISLES.—*Labradorite!* menaccanite, hypersthene, andesite, *zircon*.

MONTREAL.—*Calcite*, *augite*, sphene in trap, chrysolite, natrolite, dawsonite, sodalite, acmite.

MORIN.—*Sphene*, *apatite*, *labradorite*.

MOUNT ALBERT.—Chrysolite.

ORFORD.—White garnet, *chrome garnet*, *millerite*, serpentine, *pyroxene*.

PORTAGE DU FORT.—Rensselaerite.

POTTON.—Chromite, *steatite*, serpentine, *amianthus*.

ROUGEMONT.—Augite in trap.

ST. ARMAND.—Micaceous iron ore with quartz, epidote.

ST. FRANÇOIS BEAUCE.—Gold, platinum, iridosmine, menaccanite, magnetite, serpentine, chromite, soapstone, barite.

ST. JEROME.—*Sphene*, *apatite*, *chondrodite*, *phlogopite*, *tourmaline*, *zircon*, *garnet*, molybdenite, pyrrhotite, wollastonite, *labradorite*.

ST. NORBERT.—Amethyst in greenstone.

SHERBROOKE.—At Suffield mine, *albite! native silver*, argentite, chalcopyrite, blende.

STUKELEY.—Serpentine, *verd-antique!* schiller spar.

SUTTON.—*Magnetite* in fine crystals, hematite, *rutile*, dolomite, *magnesite*, chromiferous *talc*, bitter spar, steatite.

TEMPLETON TOWNSHIP, Ottawa County.—*Apatite!* rutile, titanite, scapolite, tourmaline (blk.), hematite (Haycock mine), wollastonite, *pyroxene*, *zircon*, *vesuvianite! phlogopite! chrysotile*, hornblende, prehnite, wilsonite, chabazite, stilbite, uralite.

THETFORD.—*Chrysotile!*

UPTON.—Chalcopyrite, malachite, calcite.

VAUDREUIL.—Limonite, vivianite.

WAKEFIELD TOWNSHIP, Ottawa County.—*Apatite!* titanite, pyroxene, *garnet*, *zircon*, vesuvianite, scapolite, phlogopite, calcite (blue), spinel, tourmaline (blk).

YAMASKA.—Sphene in trap.

PROVINCE OF ONTARIO.

ARNPRIOR.—Calcite.

BALSAM LAKE.—*Molybdenite*, scapolite, quartz, pyroxene, pyrite.

BATHURST.—Barite, *black tourmaline*, *perthite* (orthoclase), *peristerite* (albite), *bytownite*, pyroxene, wilsonite, scapolite, apatite, titanite.

BRANTFORD.—Sulphuric acid spring (4·2 parts of pure sulphuric acid in 1,000).

BROCKVILLE.—Pyrite.

BRUCE MINES on Lake Huron.—*Calcite*, dolomite, quartz, *chalcopyrite*, *chalcocite*.

BURGESS.—*Pyroxene*, albite, *mica*, corundum, sphene, chalcopyrite, *apatite*, *black spinel!* spodumene (in a bowlder), serpentine, biotite.

CALABOGIE LAKE.—Tremolite.

CAPE IPPERWASH, Lake Huron.—Oxalite in shales.

CLARENDON.—*Vesuvianite*, *tourmaline*.

CREDIT RIVER (forks of the).—Red celestite.

DALHOUSIE.—Hornblende, dolomite.

DELORO.—*Arsenopyrite!* gold, calcite, chalcodite.

DRUMMOND.—Labradorite.

ELIZABETHTOWN.—*Pyrrhotite*, *pyrite*, calcite, magnetite, talc, phlogopite, siderite, apatite, cacoxenite.

ELMSLEY.—Pyroxene, sphene, feldspar, *tourmaline*, apatite, biotite, zircon, red spinel, chondrodite.

FITZROY.—Amber, brown *tourmaline* in quartz.

GRAND CALUMET ISLAND.—*Apatite*, *phlogopite!* *pyroxene!* *hornblende*, sphene, *vesuvianite!* *serpentine*, tremolite, *scapolite*, brown and black *tourmaline!* pyrite, loganite.

HIGH FALLS OF THE MADAWASKA.—*Pyroxene!* hornblende.

INNISKILLEN.—Petroleum.

JACKFISH LAKE, Huronian Mine.—Sylvanite.

KINGSTON.—*Celestite*.

LAC DES CHATS, Island Portage.—*Brown tourmaline!* pyrite, calcite, quartz.

LANARK.—Raphilite (hornblende), serpentine, asbestus, perthite (aventurine feldspar), peristerite.

LANSDOWNE.—*Celestite*, vein 27 in. wide, and fine crystals, *rensselaerite*, sphalerite, wilsonite, labradorite.

LITTLE RIDEAU.—Celestite (fibrous).

MADOC.—Magnetite.

MARBLE LAKE, Barrie Township.—Meneghinite, galena.

MARMORA.—Magnetite, chalcolite, serpentine, garnet, epsomite, hematite, steatite, arsenopyrite, gold.

MCNAB.—Hematite, barite.

MICHIPICOTEN ISLAND, Lake Superior.—*Domeykite*, *niccolite*, *genthite*, *chalcopyrite*, native copper, native silver, chalcocite, galenite, amethyst, calcite, stilbite, analcite; at Maimanse Bay, Coracite, chalcocite, chalcopyrite, native copper.

NEWBOROUGH.—*Chondrodite*, graphite.

PAKENHAM.—Hornblende.

PERTH.—Apatite in large beds, phlogopite.

ROSS TOWNSHIP, Renfrew County.—*Apatite*, *titanite*, *hornblende*, *pyroxene*, orthoclase, *scapolite*, chrysotile, molybdenite, molybdite.

St. Adèle.—Chondrodite in limestone.
St. Ignace Island.—*Calcite*, native copper.
Sebastopol Township, Renfrew County.—*Apatite! titanite! zircon! hornblende, orthoclase*, microcline, *scapolite, pyroxene*, calcite.
Silver Islet, Lake Superior.—Argentite, native silver, galenite, niccolite, chalcocite, malachite.
South Crosby.—Chondrodite.
Sydenham.—Celestite.
Terrace Cove, Lake Superior.—Molybdenite.
Verona (near).—Black tourmaline.
Wallace Mine, Lake Huron.—Hematite, nickel ore, nickel vitriol, *chalcopyrite*.

PROVINCE OF NEW BRUNSWICK.

Albert Co.—Hopewell on Shepody Bay, gypsum, manganese ores; Albert mines, near Hillsboro', *albertite* (largely exported); Shepody Mountain, alunite in clay, calcite, pyrite, *manganite*, psilomelane, *pyrolusite*, gypsum (quarried), *anhydrite* (with the gypsum).
Carleton Co.—Woodstock, chalcopyrite, hematite, limonite, wad.
Charlotte Co.—Campobello, at Welchpool, blende, chalcopyrite, bornite, galenite, pyrite; at head of Harbor de Lute, galenite; Deer Island, on west side, calcite, magnetite, quartz crystals; Digdighash River on west side of entrance, *calcite!* (in conglomerate), chalcedony; at Rolling Dam, graphite; Grand Manan, between Northern Head and Dark Harbor, agate, amethyst, *apophyllite, calcite*, hematite, heulandite, jasper, magnetite, natrolite, *stilbite;* at Whale Cove, *calcite!* heulandite, laumontite, stilbite; *semi-opal!;* Wagaguadavic River, at entrance, azurite, chalcopyrite, in veins, malachite.
Gloucester Co.—Tête-a-Gouche River, eight miles from Bathurst, chalcopyrite (mined), *oxide of manganese!* formerly mined.
Kings Co.—Sussex, near Cloat's mills, on road to Belle Isle, argentiferous galenite; one mile north of Baxter's Inn, *hematite* in crystals, limonite; on Capt. McCready's farm, *selenite!;* at Upham, *manganese* ores, gypsum.
Restigouche Co.—Belledune Point, *calcite! serpentine, verd-antique;* Dalhousie, agate, carnelian.
St. John Co.—Black River, on coast, calcite, chlorite, chalcopyrite, *hematite!* Brandy Brook, epidote, *hornblende*, quartz crystals; Carleton, near Falls, calcite; Chance Harbor, *calcite* in quartz veins, chlorite in argillaceous and talcose slate; Little Dipper Harbor, on west side, in greenstone, amethyst, barite, quartz crystals; Moosepath, feldspar, hornblende, muscovite, black tourmaline; Musquash, on east side harbor, copperas, graphite, pyrite; at Shannon's, chrysolite, serpentine; east side of Musquash, *quartz crystals!;* Portland at the Falls, graphite; at Fort Howe Hill, *calcite*, graphite; Crow's Nest, asbestus, *chrysolite*, magnetite, *serpentine*, steatite; Lily Lake, white augite? chrysolite, graphite, serpentine, steatite talc; How's Road, two miles out, epidote (in syenyte), steatite in limestone, *tremolite;* Drury's Cove, graphite, pyrite, pyrallolite? indurated talc; Quaco, at Lighthouse Point, large bed oxide of manganese; Sheldon's Point, actinolite, asbestus, calcite, *epidote*, malachite, specular iron; Cape

Spenser, asbestus, calcite, chlorite, *specular iron* (in crystals); Westbeach, at east end on Evans's Farm, chlorite, talc, *quartz crystals;* half a mile west, chlorite, chalcopyrite, magnesite (vein), magnetite; Point Wolf and Salmon River, asbestus, chlorite, chrysocolla, chalcopyrite, bornite, pyrite.

VICTORIA CO.—Tabique River, *agate, carnelian,* jasper; at mouth, south side, galenite; at mouth of Wapskanegan, gypsum, salt spring; three miles above, stalactites (abundant); Quisabis River, blue phosphate of iron, in clay.

WESTMORELAND CO.—Bellevue, pyrite; Dorchester, on Taylor's Farm, cannel coal; clay ironstone; on Ayer's Farm, asphaltum, petroleum spring; Grandlance, apatite, selenite (in large crystals); Memramcook, coal (albertite); Shediac, four miles up Scadoue River, coal.

YORK CO.—Near Fredericton, Prince William mine, *stibnite* (mined), *native antimony,* jamesonite, berthierite; Pokiock River, stibnite, *tin pyrites?* in granite (rare).

PROVINCE OF NOVA SCOTIA.

ANNAPOLIS CO.—Chute's Cove, *apophyllite,* natrolite; Gates's Mountain, analcite, magnetite, *mesolite! natrolite,* stilbite; Martial's Cove, *analcite!* chabazite, *heulandite;* Moose River, beds of magnetite; Nictau River, at the Falls, bed of hematite; Paradise River, black tourmaline, *smoky quartz!;* Port George, faröelite, laumontite, mesolite, stilbite; east of Port George, on coast, apophyllite containing gyrolite; Peter's Point, west side of Stonock's Brook, *apophyllite!* calcite, heulandite, *laumontite!* (abundant), native copper, stilbite; St. Croix's Cove, chabazite, heulandite.

ANTAGONISH CO.—College Lake, *chalcopyrite;* on St. George's Bay, and elsewhere, *gypsum,* in thick strata.

CAPE BRETON CO.—At Gabarus, *molybdenite,* bismuth glance; at Loch Lomond, Salmon River, *manganese ore;* at Plaister Cove, Mabou, Port Hood, etc., *gypsum;* near Sydney, copper ores.

COLCHESTER CO.—Five Islands, East River, *barite,* calcite, dolomite (ankerite), hematite, chalcopyrite; Indian Point, malachite, magnetite, red copper, tetrahedrite; Pinnacle Islands, *analcite,* calcite, *chabazite!* natrolite, siliceous sinter; Londonderry, on branch of Great Village River. *barite!* ankerite, *hematite, limonite, magnetite;* Cook's Brook, ankerite, hematite; Martin's Brook, hematite, limonite; at Folly River, below Falls, ankerite, pyrite; on high land, east of river, ankerite, hematite, limonite; on Archibald's land, ankerite, *barite,* hematite; Salmon River, south branch of, chalcopyrite, hematite; Shubenacadie River, anhydrite, calcite, *barite,* hematite, oxide of manganese; at the Canal, pyrite; Stewiacke River, *barite* (in limestone; 300 tons mined in 1885); at Onslow, *manganese ore.*

CUMBERLAND CO.—Cape Chegnecto, barite; Cape d'Or, *analcite, apophyllite!* chabazite, faröelite, laumontite, *mesolite,* malachite, *natrolite, native copper,* obsidian, red copper (rare), vivianite (rare); Horse Shoe Cove, east side of Cape d'Or, analcite, calcite, stilbite, Isle Haute, south side, analcite, *apophyllite!* calcite, *heulandite!* natrolite, mesolite, *stilbite!;* Joggins, coal, hematite, limonite; malachite and tetrahedrite at Seaman's Brook; Partridge Island, analcite,

apophyllite! (rare), *amethyst!* agate, apatite (rare), *calcite!* chabazite (acadialite), chalcedony, cat's-eye (rare), gypsum, hematite, *heulandite!* magnetite, *stilbite!;* Swan's Creek, west side, near the Point, calcite, gypsum, *heulandite*, pyrite; east side, at Wasson's Bluff and vicinity, *analcite! apophyllite!* (rare), *calcite, chabazite!* (acadialite), gypsum, *heulandite! natrolite!* siliceous sinter; Two Islands, moss agate, analcite, calcite, chabazite, *heulandite;* McKay's Head, analcite, calcite, heulandite, *siliceous sinter!;* at Amherst, manganese ore.

DIGBY CO.—Briar Island, native copper, in trap; Digby Neck, Sandy Cove and vicinity, *agate, amethyst, calcite, chabazite, hematite! laumontite* (abundant), magnetite, *stilbite*, quartz crystals; Gulliver's Hole, *magnetite, stilbite!;* Mink Cove, amethyst, *chabazite!* quartz crystals; Nichols Mountain, south side, *amethyst, magnetite!;* Williams Brook, near source, *chabazite* (green), heulandite, stilbite, quartz crystal.

GUYSBORO' CO.—Cape Canseau, *andalusite.*

HALIFAX CO.—Gay's River, galenite in limestone; southwest of Halifax, garnet, staurolite, tourmaline; Tangier, *gold!* in quartz veins in clay slate, associated with auriferous pyrite, galenite, hematite, arsenopyrite, and magnetite; gold at Country Harbor, Fort Clarence, Isaac's Harbor, Indian Harbor, Laidlow's Farm, Lawrencetown, Sherbrooke, Salmon River, Wine Cove, and other places; at Hammond's Plains and Musquodoboit, molybdenite.

HANTS CO.—Cheverie, *oxide of manganese* (in limestone), *gypsum;* Petite River, gypsum, oxide of manganese; Walton, *pyrolusite, manganite;* Teny Cape, manganese ores; Windsor, calcite, *gypsum* (great bed), with cryptomorphite (baronatrocalcite), howlite, glauber salt; at Rawdon, *stibnite*, of which 758 tons (valued at $33,095) were exported in 1885; at Teny Cape, *manganese ore.*

KINGS CO.—Black Rock, centrallassite, cerinite, cyanolite; a few miles east of Black Rock, prehnite? *stilbite!;* Cape Blomidon, on the coast between the cape and Cape Split, the following minerals occur in many places (some of the best localities are nearly opposite Cape Sharp): *analcite! agate, amethyst! apophyllite!* calcite, chalcedony, chabazite, *gmelinite* (lederite), hematite, *heulandite!* laumontite, magnetite, malachite, *mesolite*, native copper (rare), *natrolite!* psilomelane, *stilbite!* thomsonite, faröelite, *quartz;* North Mountains, amethyst, bloodstone (rare), *ferruginous quartz, mesolite* (in soil); Long Point, five miles west of Black Rock, *heulandite, laumontite! stilbite!;* Morden, *apophyllite, mordenite;* Scott's Bay, *agate*, amethyst, *chalcedony*, mesolite, natrolite; Woodworth's Cove, a few miles west of Scott's Bay, *agate! chalcedony! jasper.*

LUNENBURG CO.—Chester, Gold River, gold in quartz, pyrite, mispickel; Cape la Have, pyrite; The "Ovens," *gold*, pyrite, arsenopyrite; Petite River, gold in slate.

PICTOU CO.—Pictou, *jet*, oxide of manganese, limonite; at Roder's Hill, six miles west of Pictou, barite; on Caribou River, gray copper and malachite in lignite; at Albion mines, coal, limonite; East River, limonite, hematite, magnetite, siderite, ankerite; on Sutherland's R., *siderite;* at Smithfield, argentiferous galenite.

QUEEN'S CO.—Westfield, gold in quartz, pyrite, arsenopyrite; Five Rivers, near Big Fall, gold in quartz, pyrite, arsenopyrite, limonite.

RICHMOND CO.—West of Plaister Cove, barite and calcite in sandstone; nearer the Cove, calcite, *fluorite* (blue), siderite; *gypsum* in beds of great thickness (giving the name to Plaister Cove).

SHELBURNE CO.—Shelburne, near mouth of harbor, garnets (in gneiss); near the town, rose quartz; at Jordan and Sable River, *staurolite* (abundant), schiller spar.

SYDNEY CO.—Hills east of Lochaber Lake, pyrite, chalcopyrite, siderite, hematite; Morristown, epidote in trap, *gypsum* (making a cliff of 200 feet, near Ogden's Lake).

YARMOUTH CO.—Cream Pot, above Cranberry Hill, gold in quartz, pyrite; Cat Rock, Fourchu Point, asbestus, calcite.

PROVINCE OF BRITISH COLUMBIA.

CARIBOO DISTRICT.—Native gold, galena.

ON FRAZER RIVER.—Gold, argentiferous tetrahedrite, cerargyrite, cinnabar.

OMINICA DISTRICT.—Native gold, argentiferous galenite, native silver, silver-amalgam.

HOWE'S SOUND.—Bornite, molybdenite, mica.

TEXADA ID.—Magnetite.

SHUSWAP LAKE.—*Bismuthinite.*

NEWFOUNDLAND.

ANTONY'S ISLAND.—*Pyrite.*

CATALINA HARBOR.—On the shore, *pyrite!*

CHALKY HILL.—*Feldspar.*

COPPER ISLAND, one of the Wadham group.—*Chalcopyrite.*

CONCEPTION BAY.—On the shore south of Brigus, bornite and gray copper in trap.

BAY OF ISLANDS.—Southern shore, *pyrite* in slate.

LAWN.—*Galenite, cerargyrite, proustite, argentite.*

PLACENTIA BAY.—At La Manche, two miles eastward of Little Southern Harbor, *galenite!*; on the opposite side of the isthmus from Placentia Bay, barite in a large vein, occasionally accompanied by chalcopyrite.

SHOAL BAY.—South of St. John's, chalcopyrite.

TRINITY BAY.—Western extremity, barite.

HARBOR GREAT ST. LAWRENCE.—West side, fluorite, galenite.

V. DETERIMNATION OF MINERALS.

In the determination of minerals, no one order in the succession in which characters should be examined answers for all minerals, or even for all of the same section of species.

The points to be first examined are: *Hardness*, which may be tried by the point of a knife-blade, if a file or scale of hardness is not at hand; and *fusibility* before the blowpipe, with other blowpipe reactions; and, in the case of species of unmetallic lustre, solubility or not in hydrochloric acid (HCl), the dilute acid serving to test effervescence from the escape of carbonic acid (carbon dioxide, CO_2), and the strong acid, to ascertain whether the mineral gelatinizes or not, and other points already explained.

For species having a metallic lustre, the order of easiest application is generally, after trials of hardness, fusibility, and blowpipe reactions: *Color; sectility*, which distinguishes argentite, amalgam, and some native metals from other species of metallic lustre; *streak*, whether metallic or not, and the color of the powder or rubbed surface; *specific gravity*, care being taken that the specimen is pure; action of nitric acid; *crystalline form* and *cleavage*, a character of the highest importance; *optical characters*, in species that transmit light when in thin slices.

For species without metallic lustre, after trial of hardness, B.B. characters, and solubility in acid: *Color*, but with doubt of its value, as impurities often cause great variations; *streak*, when it is decidedly colored; *specific gravity; sectility*, when perfect like that of wax, which distinguishes cerargyrite and a related species; crystalline form and cleavage; *taste*, in the case of soluble species; *optical characters*, which are always important, and may be the best available means.

The following hints may be of service to the beginner in the science, by enabling him to overcome a difficulty in the outset, arising from the various forms and appearance of the minerals quartz and limestone. Quartz occurs of nearly every color, and of various degrees of glassy lustre to a dull stone without the slightest glistening. The common grayish cobble-stones of the fields are usually quartz, and others

are dull red and brown; from these there are gradual transitions to the pellucid quartz crystal that looks like the best of glass. Sandstones are often wholly quartz, and the seashore sands are mostly of the same material. It is therefore probable that this mineral will be often encountered in mineralogical rambles.

Let the first trial of specimens obtained be made with a file, or the point of a knife, or some other means of trying the hardness; if the file makes no impression, there is reason to suspect the mineral to be quartz; and if on breaking it, no regular structure or cleavage plane is observed, but it breaks in all directions with a similar surface and a more or less vitreous lustre, the probability is much strengthened that this conclusion is correct. The blowpipe may next be used; and if there is no fusion produced by it in a careful trial there can be little doubt that the specimen is in fact quartz.

Calcite (calcium carbonate), including limestone, is another very common species. If the mineral collected is rather easily impressible with a file, it may be of this species; if it effervesces freely when placed in a test-tube containing dilute hydrochloric acid, and is finally dissolved, the probability of its being carbonate of lime is increased; if the blowpipe produces no trace of fusion, but a brilliant light from the fragment before it, but little doubt remains on this point. Crystalline fragments of calcite break with three equal oblique cleavages.

Familiarized with these two Protean minerals by the above and other trials, the student has already surmounted the principal difficulties in the way of future progress. Frequently the young beginner who has devoted some time to collecting the differently colored stones in his neighborhood, on presenting them for names to some practised mineralogist, is a little disappointed to learn that, with two or three exceptions, his large variety includes nothing but limestone and quartz. He is perhaps gratified, however, at being told that he may call this specimen yellow jasper, that red jasper, another flint, and another hornstone, others chert, granular quartz, ferruginous quartz, chalcedony, prase, smoky quartz, greasy quartz, milky quartz, agate, plasma, hyaline quartz, quartz crystal, basanite, radiated quartz, tabular quartz, etc., etc.; and it is often the case, in this state of his knowledge, that he is

best pleased with some treatise on the science in which all these various stones are treated with as much prominence as if actually distinct species; being loath to receive the unwelcome truth, that his whole extensive cabinet contains only one mineral. But the mineralogical student has already made good progress when this truth is freely admitted, and quartz and limestone, in all their varieties, have become known to him.

The student should be familiar with the use of the blowpipe and the reactions, as explained on pages 93 to 102; it would be still better if a fuller treatise on the subject had been carefully studied. He should be supplied with the three acids in glass-stoppered bottles; a fourth bottle containing hydrochloric acid diluted one half with water, for obtaining effervescence with carbonates; test-tubes; and also the ordinary blowpipe apparatus and tests, including platinum wire, platinum forceps, glass tube, "cobalt solution," litmus and turmeric paper, etc.

Also the following:

A *small file*, three-cornered or flat, for testing hardness.

A *knife* with a pointed blade of good steel, for trying hardness. It may be magnetized, to be used as a magnet, though a good horseshoe *magnet* of small size is better.

The series of crystallized minerals, constituting the *scale of hardness* (see page 67). Diamond and talc are least essential.

Cutting pliers, for removing chips of a mineral for blowpipe or chemical assay.

A *pocket-lens*.

A *hammer* weighing about two pounds, resembling a stone-cutter's hammer, having a flat face, and at the opposite end an edge having the same direction as the handle. The handle should be made of the best hickory, and the mortise to receive it should be as large as the handle. A foot scale should be marked on the handle of the hammer, divided into inches, the smallest divisions needed. It will be often of use in getting out a yard-stick, or a ten-foot pole, for large measurements. A similar hammer, having the upper part prolonged to a blunt point, to be used like a pick, is often convenient.

A hammer of half a pound weight, like the figure, to be used in trimming specimens.

A small jeweler's hammer, for trying the malleability of globules obtained by the blowpipe, and for other purposes, and a small piece of steel for an anvil.

Two steel stone chisels, one six inches long, and the other three. When it is desired to pry open seams in rocks with the larger chisel, two pieces of steel plate should be provided to place on opposite sides of the chisel, after an opening is obtained; this protects the chisel and diminishes friction while driving it.

For blasting, if this is desired:

Three hand-drills, 18, 24, and 36 inches long, an inch in diameter. The best form is a square bar of steel, with a diagonal edge at one end. The three are designed to follow one another.

A sledge-hammer of six or eight pounds weight, to use in driving the drill.

A sledge-hammer of ten or twelve pounds weight, for breaking up the blasted rock.

A round iron spoon, at the end of a wire fifteen or eighteen inches long, for removing the pulverized rock from the drill-hole.

A crowbar, a pickaxe, and a hoe for removing stones and earth before or after blasting.

Cartridges of blasting powder, to use in wet holes. They should one third fill the drill-hole. After the charge is put in, the hole should be filled with sand and gravel alone without ramming. If any ramming material is used, plaster of Paris is the best, which has been wet and afterwards scraped to a powder.

Patent fuse for slow match, to be inserted in the cartridge, and to lead out of the drill-hole.

The table beyond is prepared especially to aid in instruction, and comprises, with few exceptions, only the species that are described in large type through the work, exclusive of the hydrocarbon compounds. Before commencing with the table in the determination of a mineral, it is best to make the preliminary trials mentioned on page 405. Moreover, the brief description of a species should be supplemented, whenever a doubt arises, by turning to the full description in the earlier part of the book.

The following abbreviations are used in the table, in addition to those explained on page 102. With reference to colors: *bnh,* brownish; *bkh,* blackish; *gnh,* greenish; *gyh,* grayish; *rdh,* reddish. The acids: *nit.,* nitric acid; *sulph. acid,* sulphuric acid; *HCl.,* hydrochloric acid; *sulph.,* sulphur or sulphurous acid.

Reactions: *gelatinizing with acid,* see page 92; *reaction for sulphur with soda,* see page 101; *blue* or *red color with cobalt solution,* see page 98; *hydrous,* yielding water in a closed tube; *anhydrous,* not yielding water in a closed tube, or only traces, see page 98; B.B. *lithium-red color,* see page 98; B.B. *green flame due to boron,* see page 99; *coal* is used for charcoal; *fus.* for fusible; *infus.* for infusible; *sol.* for soluble; *st.* for streak.

In using the blowpipe it is important to remember that a trial of fusibility with the forceps, if not at once producing fusion, should be made on a piece of the mineral not larger than the fourth of an ordinary pin-head, and it should be either oblong and slender, or thin, and be made to project considerably beyond the points of the forceps, lest the forceps carry off the heat, and cause a failure where there ought to be success. Further, it should be in mind, that in using charcoal, a white coating is always a consequence of burning it, since the ash from its own combustion is white. Again, before testing for sulphur by means of soda and a polished surface of silver, it is necessary to try the flame and the soda for sulphur. Gas-flame always contains traces of sulphur, and sometimes too much for safe conclusions in this trial.

A mineralogist sometimes has occasion to measure distances, and by the following method he may make himself quite an accurate odometer:

Let him first find, or make, along a roadside, a measured distance of 800 to 1000 feet, and then walk it at his ordinary walking pace three or four times, and note the number of steps. He will thus ascertain the actual length of his pace, and also find that in his ordinary walk it does not differ much from thirty inches; it may be an inch or two less, or one, two, or three more than this. Now four times thirty inches is ten feet. If then, as he walks, he counts one for every *fourth step,* each unit in the count will stand for ten feet nearly, and 100 for 1000 feet nearly. If his pace is thirty-one inches, let him add a unit for every

thirty in the counting, or, which is the same thing, call his thirty thirty-one, and the needed correction will be made; or if his step is twenty-nine and one half inches, subtract one from every sixty in the counting, or in other words duplicate the sixtieth. Or the correction may be made at the end of the pacing; if at 600, this number, after adding a thirtieth, becomes 620; and the distance would hence be 6200 feet. With a little practice the counting may be carried on almost unconsciously, and when the thoughts are elsewhere; that is, unless there is a talking friend by one's side.

An instrument, called a *pedometer*, of the shape and size of a small watch, is to be had of instrument-makers, which, if carried in the waistcoat pocket, will do the registering for the pedestrian and note the distance, without any attention on his part. But the odometer explained above, when once in working order, is always at hand; moreover, the pocket pedometer measures miles, and not feet or yards.

SYNOPSIS OF THE ARRANGEMENT.

I. ELEMENTS.

(None of the species in the other subdivisions have the characters here enumerated:)

1. Lustre metallic; liquid.
2. Lustre metallic; malleable and eminently sectile.
3. Lustre metallic; brittle; B.B. on coal, wholly volatile, with no sulphurous fumes.
4. Lustre metallic; brittle; H. = 1–2; leaves a trace on paper; B.B. on coal, infusible, no fumes or odor.
5. Unmetallic; burns readily with a blue flame.
6. Lustre adamantine; H. = 10.

II. MINERALS NOT ELEMENTS THAT B.B. ON COAL ARE WHOLLY VOLATILE.

1. Lustre metallic; streak metallic.
2. Lustre unmetallic; streak same as color.

III. COMPOUNDS OF GOLD, SILVER, COPPER, LEAD, TIN, MERCURY, CHROMIUM, COBALT, MANGANESE: yielding, on heating, a malleable, or

liquid (for mercury ores), metallic globule, or else affording a decisive blowpipe reaction proving the presence of one or more of these metals.

A. Yielding a malleable globule B.B. on coal with, if not without soda.

1. Compounds of Gold.
2. Compounds of Silver.
3. Compounds of Copper.
4. Compounds of Lead.
5. Compounds of Tin.

B. Yielding drops of mercury when heated with soda, in a closed tube.

1. Compounds of Mercury.

C. A decisive reaction with borax or salt of phosphorus for chromium, cobalt, or manganese.

1. Compounds of Chromium.
2. Compounds of Cobalt.
3. Compounds of Manganese.

IV. MINERALS OF METALLIC OR SUBMETALLIC LUSTRE, NOT INCLUDED IN PRECEDING DIVISIONS.

1. Yielding fumes in the open tube or on coal, but not wholly vaporizable.

A. Streak metallic.
B. Streak unmetallic.
   a. Fumes sulphurous only.
   b. Fumes arsenical, with or without sulphurous.

2. Not yielding fumes of any kind; streak unmetallic.

A. B.B. easily fusible, giving a magnetic bead; lustre submetallic.
B. Infusible, or nearly so.
   a. Reaction for iron; anhydrous.
   b. Reaction for iron; hydrous.
   c. Reaction for chromium or titanium.
   d. Reaction for osmium with nitre.

V. MINERALS OF UNMETALLIC LUSTRE.

1. Having an acid, alkaline, alum-like, or styptic taste.

A. CARBONATES: Taste alkaline; effervescing with HCl.
B. SULPHATES: No effervescence; reaction for sulphur with soda.
C. NITRATES: With sulph. acid, reddish acrid fumes; no action with HCl; deflagrate.
D. CHLORIDES: With sulph. acid, acrid fumes of HCl; no fumes with HCl.
E. BORATES: No effervescence; reaction for boron when moistened with sulph. acid.

2. Not having either of the above-mentioned kinds of taste.

A. CARBONATES: Effervescing with HCl.
a. Infusible; assay alkaline after ignition.
b. Infusible; become magnetic and not alkaline, on ignition.
c. Infusible; B.B. on coal with soda, zinc oxide vapors.
d. Infusible; B.B. on coal reaction for nickel.
e. Fusible; assay alkaline after ignition.

B. SULPHATES: Reaction for sulphur with soda.
a. Fusible; assay alkaline after fusion.
b. Fusible; reaction for iron.
c. Infusible.

C. ARSENATES: on coal arsenical fumes.

D. SILICATES, PHOSPHATES, OXIDES.

Species not included in the preceding subdivisions.

I. STREAK DEEP RED, YELLOW, BROWNISH-YELLOW, GREEN, OR BLACK.

A. Infusible, or fusible with difficulty.
B. Fusible without much difficulty.

II. STREAK GRAYISH OR NOT COLORED.

1. Infusible.

A. Gelatinize with acid, forming a stiff jelly.
B. Not forming a stiff jelly; hydrous.
a. Blue color with cobalt solution.
b. Reddish or pink color with cobalt solution.
c. Not blue or red with cobalt solution.

C. Not forming a stiff jelly; anhydrous.
  a. Blue color with cobalt solution.
  b. Not blue or reddish color with cobalt solution.

2. Fusible with more or less difficulty.

A. Gelatinize and form a stiff jelly.
  a. Hydrous; fuse easily.
  b. Hydrous; fuse with much difficulty.
  c. Anhydrous.
    α. No reaction for sulphur; no coating on coal.
    β. Reaction for sulphur with soda.

B. Not gelatinizing.
  1. Structure eminently micaceous; folia tough, pearly, and H. of surface of folia not over 3·5; anhydrous or hydrous.
  2. Structure not eminently micaceous.
    a. Hydrous.
      α. No reaction for phosphorus, or boron.
        †. H. = 1 to 3; lustre not at all vitreous.
        ††. H. = 3·5–6·5; lustre of cleavage surface sometimes pearly; elsewhere vitreous.
      β. Reaction for phosphorus or boron.
    b. Anhydrous.
      α. B.B. lithium-red flame.
      β. B.B. boron reaction (green flame).
      γ. B.B. reaction for titanium.
      δ. B.B. reaction for fluorine or phosphorus.
      ϵ. B.B. reaction for iron.
      θ. B.B. no reaction for iron; not of the preceding subdivisions.

I. ELEMENTS.

1. Lustre metallic; liquid.

MERCURY, p. 142. This is the only metallic mineral which is liquid at the ordinary temperature and atmospheric pressure.

2. Lustre metallic; malleable and eminently sectile.

GOLD, p. 122. G. = 15–19·5; yellow; fusible; not sol. in nitric acid or HCl, but sol. in aqua regia.

PLATINUM, p. 139. G. = 16–19; nearly white; infusible; insol. in nitric acid.

PALLADIUM, p. 141. G. = 11·3–11·8; grayish-white; diff. fusible; sol. in nitric acid.

SILVER, p. 129. G. = 10–11·1; white; fusible; sol. in nitric acid, and deposited again on copper.

COPPER, p. 145. G. = 8·84; copper-red; fus.; sol. in nitric acid, and the solution becomes sky-blue when ammonia is added.
IRON, p. 189. G. = 7·3–7·8; iron-gray; attracted by the magnet.

The only other mineral of metallic lustre that is also malleable and eminently sectile is *argentite*, a silver sulphide, along with two others of like composition but different crystallization.

3. Lustre metallic; brittle; B.B. wholly volatile, but give off no sulphurous fumes; H. = 2–3·5.

BISMUTH, p. 113. G. = 9·73; reddish-white; on coal a yellow coating; fumes inod.
ANTIMONY, p. 112. G. = 6 6–6·7 tin-white; fumes dense wh., inod.
ARSENIC, p. 110. G. = 5·9–6; tin-white; fumes white, alliaceous.
TELLURIUM, p. 108. G. = 6·1–6·3; tin-white; fus.; fumes white; flame green.

The only other mineral that is wholly volatile, and also gives off no sulphurous fumes, is allemontite, an antimony arsenide.

4. Lustre metallic; H. = 1–2; B.B. on coal infusible; no fumes.

GRAPHITE, p. 119.

5. Lustre unmetallic; takes fire readily in the flame of a candle, and burns with a blue flame.

SULPHUR, p. 106.

6. Lustre adamantine; H. = 10.

DIAMOND, p. 115. Easily scratches corundum or sapphire.

II. MINERALS, NOT ELEMENTS, THAT ARE WHOLLY VOLATILE B.B. ON COAL.

1. Lustre metallic; streak metallic; H. = 1–2.

TETRADYMITE, p. 114. G. = 7·2–7·9; pale steel-gray; so soft as to soil paper; on coal white fumes; flame bluish green; sometimes sulph. odor; in open tube, a coating which fuses to white drops.
BISMUTHINITE, p. 114. G. = 6·4–7·2; whitish lead-gray; on coal yellow coating and sulph. odor.
STIBNITE, p. 112. G. = 4·5–4·52; lead-gray; on coal dense wh. fumes and wh. coating.

2. Lustre unmetallic; streak same nearly as color, except in cinnabar, in which it is always bright red. H. = 1–3.

ORPIMENT, p. 111. Lemon yellow; on coal burns, odor alliaceous.
REALGAR, p. 111. Bright red; on coal burns, odor alliaceous.
ARSENOLITE, p. 111. White; on coal, odor alliaceous.
VALENTINITE, p. 113. White; on coal dense wh. fumes, inod.
CINNABAR, p. 143. Red; in open tube, sulph. odor, coating of mercury globules.
SALMIAK, p. 249. White; saline and pungent taste; on coal, fumes of ammonia.

III. COMPOUNDS OF GOLD, SILVER, MERCURY, COPPER, LEAD, TIN, CHROMIUM, COBALT, MANGANESE.

A. Yielding a malleable globule B.B. on coal, with or without soda.

1. COMPOUNDS OF GOLD.

Yield gold, or an alloy of gold and silver, B.B. on coal.

The TELLURIUM ORES, pp. 129, 132, give a coating of drops of tellurous acid in open tube (p. 101).

2. COMPOUNDS OF SILVER.

B B. easily fusible; G. above 5; yield, with few exceptions, a globule of silver (white and malleable) on coal, with soda, if not without; and, in the exceptions, silver globule obtained by cupellation. All have metallic lustre excepting cerargyrite, bromyrite, and iodyrite.

a. EMINENTLY SECTILE.

ARGENTITE, p. 131. G. = 7·2–7·4; lustre metallic; H. = 2; on coal sulph. fumes.
CERARGYRITE, p. 134. H. = 1–2; G. = 5·3–5·6; lustre like that of white, gray, or greenish to brownish wax; see also related species, p. 134.

b. NOT SECTILE; ON COAL ODOROUS FUMES.

SULPHIDES, p. 131. Gives sulph. odor.
ARSENICAL ORES, p. 132 Alliaceous fumes.
SELENIDES, p. 131. Horse radish odor.

c. NOT SECTILE; ON COAL FUMES OF ANTIMONY OR TELLURIUM.

ANTIMONIAL ORES, pp. 132, 133. Dense white fumes of antimony; with also, if sulphur is present, sulph. fumes.

TELLURIDES, pp. 131, 132. In open tube coating which fuses to drops of tellurous acid.
STROMEYERITE, p. 131. Contains copper, and requires cupellation in order to obtain a globule of silver.

3. COMPOUNDS OF COPPER.

Unless iron is present, a globule of metallic copper is obtained with soda, if not without, on coal; with a nitric acid solution and ammonia in excess a bright blue color; moistened with HCl the blue flame of chloride of copper; and a clean surface of iron in the nitric solution becomes coated with copper.

1. METALLIC LUSTRE.

SULPHIDES, pp. 146–148. On coal or in open tube sulph. fumes; H. = 2–4.
ARSENIDES, SELENIDES, p. 149; H. = 2–4.
ANTIMONIAL SULPHIDES, pp. 149, 150; H. = 2–4·5.

2. LUSTRE UNMETALLIC; B.B. NEITHER ON COAL NOR IN OPEN TUBE ANY ODOROUS FUMES; NO TASTE.

CUPRITE, p. 151. H. = 3·5–4; G. = 5·8–6·2; isometric; deep red, streak bnh-red.
ATACAMITE, p. 150. Darkish bright green, streak gnh; BB. on coal fuses, coloring O.F. azure-blue, with a green edge; easily sol. in acids.
PHOSPHATES, p. 153. H. = 2–5; G. = 2·8–4·5.
MALACHITE, p. 154. H. = 3–4; G. = 3·7–4; light to deep green; effervesces with HCl.
AZURITE, p. 156. H. = 3·5–4·5; G. = 3·5–3·9; deep blue; effervesces with HCl.
DIOPTASE, p. 156. H. = 5; G. = 3·25–3·35; never fibrous; emerald-green; B.B. infusible.
CHRYSOCOLLA, p. 157. Bluish green; B.B. infusible; amorphous.

3. LUSTRE UNMETALLIC; B.B. ON COAL, OR IN CLOSED TUBE, ODOROUS FUMES OF ARSENIC OR SULPHUR, OR REACTION FOR SULPHUR.

ARSENATES, p. 153. On coal arsenical fumes; H. = 2–3.
CHALCANTHITE, p. 152. Blue; taste nauseous; astringent.
Also *Stromeyerite*, *Stannite*, *Bournonite* give reactions for copper.

4. COMPOUNDS OF LEAD.

Yield B.B. on coal a dark lemon-yellow coating; finally, with soda, if not without, a globule (metallic and malleable) of lead is obtained; but by continued blowing with O.F. the lead all goes off in fumes, leaving other more stable metals (silver, etc.) behind. Sulphurous, selenious, and tellurous fumes easily obtained either on coal or in an open tube from the sulphide, selenide, tellurides; and arsenical or antimonial fumes from ores containing arsenic or antimony. None have taste; none have H. above 4.

1. LUSTRE METALLIC.

GALENITE, p. 160. H. = 2·5; G. = 7·2–7·7; cleavage cubic eminent; lead-gray, streak same; in open tube sulph.
SELENIDES, TELLURIDES, ANTIMONIAL and **ARSENICAL SULPHIDES**, pp. 160–164.

2. LUSTRE UNMETALLIC; NO ODOROUS FUMES, OR REACTION FOR SULPHUR.

MINIUM, p. 165. Bright red, streak same.
CROCOITE, p. 166. Monoclinic; bright red, streak orange-yellow; B.B. with salt of phosphorus emerald-green bead.
PYROMORPHITE, p. 167. Hexagonal, 6-sided prisms; bright green, brown, rarely orange-yellow; streak white. B.B. fuses easily, coloring flame bluish green.
VANADINITE, p. 168. Hexagonal prisms, like pyromorphite; G. = 6·6–7·2; yellow, bnh-yw, straw yellow. B.B. fuses easily, reaction for vanadium.
CERUSSITE, p. 168. Orthorhombic, often in twins; H. = 3–3·5; G. = 6·4–6·8; white, gyh; lustre adamantine; often tarnished to grayish metallic adamantine. Effervesces in dilute nitric acid.

3. UNMETALLIC; REACTION FOR SULPHUR.

ANGLESITE, p. 165. Orthorhombic; white, gyh; fuses in flame of candle; B.B. reaction for sulphur; no effervescence with acids.

5. COMPOUNDS OF TIN.

CASSITERITE, p. 176. H. = 6–7; G. = 6·4–7·1; tetragonal; brown, gyh, ywh, black; B.B. infusible; on coal with soda a globule of tin, yield no fumes.
Stannite, p. 176. A copper, iron, and tin sulphide, does not give B.B. a metallic malleable globule.

B. Yields drops of mercury in closed tube with or without soda.

COMPOUNDS OF MERCURY.

CINNABAR, p. 143. H. = 2–2·5; G. = 8–9; rhombohedral; bright red, bnh red, gyh; streak scarlet.
AMALGAM, p. 130. H. = 3–3·5; G. = 13–14; silver-white; yields silver B.B. on coal.
A variety of tetrahedrite, p. 150, yields mercury.

C. No malleable globule; decisive reaction with borax or salt of phosphorus for chromium, cobalt, or manganese.

1. COMPOUNDS OF CHROMIUM.

Give with borax an emerald-green bead in both flames.

CHROMITE, p. 197. H. = 5·5; G. = 4·3–4·5; isometric, often in octahedrons, massive; submetallic; bnh iron-black, streak brown; B.B. on coal becomes magnetic; with borax, a bead which is emerald-green on cooling.

CROCOITE, p. 166. H. = 2·5–3; G. = 5·9–6·1; monoclinic; bright red, streak orange; B.B. fuses very easily, on coal globule of lead, and with salt of phosphorus emerald green bead. *Phœnicochroite* and *Vauquelinite* are other lead chromates.

2. COMPOUNDS OF COBALT.

Give a blue color with borax after, if not before, roasting.

[When much nickel or iron is present the blue color is not obtained; and species or varieties of this kind are not here included.]

1. LUSTRE METALLIC.

COBALTITE, p. 182. H. = 5·5; G. = 6–6·3; isometric and pyritohedral; rdh silver-white, streak grayish black; B.B. on coal sulph. and arsen. fumes, and a magnetic globule.

SMALTITE, p. 181. H. = 5·5–6; G. = 6·4–7·2; isometric; tin-white, streak gyh black; B.B. on coal alliaceous fumes; most varieties fail to give the blue color immediately with borax, because of the iron and nickel present.

LINNÆITE, p. 181. H. = 5·5; G. = 4·8–5; isometric; pale steel-gray, copper-red tarnish, streak bkh gray. B.B. on coal sulph. fumes.

2. LUSTRE UNMETALLIC.

ERYTHRITE, p. 184. H. = 1·5–2·5; G. = 2·95; monoclinic, one highly perfect cleavage, also earthy; rose-red, peach-blossom red, streak reddish; B.B. fuses easily; yields water.

BIEBERITE, p. 185. A cobalt sulphate.

REMINGTONITE, p. 185. A hydrous cobalt carbonate.

3. COMPOUNDS OF MANGANESE.

Give an amethystine globule in O.F. with borax. [The globule looks black if too much of the manganese mineral is used, and with a large excess may be opaque.]

1. GIVES OFF CARBONIC ACID WHEN TREATED WITH DILUTE HCl; LUSTRE UNMETALLIC.

RHODOCHROSITE, p. 210. H. = 3·5–4·5; G. = 3·4–3·7; rose-red.

Also manganese-bearing varieties of calcite, dolomite, ankerite, siderite, all of which have the cleavage and general form of rhodochrosite; when containing one per cent. or more of manganese they often turn black on exposure.

2. TREATED WITH HCl YIELDS CHLORINE FUMES.

MANGANITE, p. 207. H. = 4; G. = 4·2–4·4; in oblong orthorhombic prisms; grayish black, streak reddish brown; lustre submetallic; B.B. infusible; yields water.

PSILOMELANE, p. 207. H. = 5–7; G. = 3·7–4·7; amorphous; black, streak brownish black; submetallic; B.B. infusible; yields water.

Wad is similar, but often contains cobalt.

PYROLUSITE, p. 206. H. = 2–2·5; G. = 4·82; in stoutish orthorhombic crystals; metallic; dark steel-gray, streak black or bluish black; B.B. infusible; yields no water.

BRAUNITE and **HAUSMANNITE** (p. 207) are other anhydrous manganese oxides.

FRANKLINITE, p. 197. H. = 5·5–6·5; G. = 5–5·1; in isometric octahedrons and massive; iron-black, streak dark reddish brown; B.B. infusible; but little chlorine with HCl; sometimes a little magnetic.

3. CO_2 OR Cl NOT GIVEN OFF WHEN TREATED WITH HCl; ANHYDROUS.

RHODONITE, p. 268. H. = 5·5–6·5; G. = 3·4–3·68; rose-red; B.B. fuses easily.

TRIPLITE, p. 209. H. = 5·5; G. = 3·4–3·8; brown to black; B.B. fuses very easily, globule magnetic; sol. in HCl.

HELVITE, p. 278. H. = 6–6·5; G. = 3·1–3·3; in yellowish tetrahedrons; B.B. fuses easily.

SPESSARTITE (Manganesian Garnet), p. 279. H. = 6·5–7; G. = 3·7–4·4; in dodecahedrons and trapezohedrons; red, brownish red; B.B. fuses easily.

TEPHROITE, p. 277. H. = 5·5–6; G. = 4–4·12; orthorhombic; reddish to brown and gray; B.B. fuses not very easily; gelat. in HCl.

Knebelite, p. 277, is related, and also gelatinizes.

HAUERITE, p. 206. H. = 4; G. = 3·46; isometric; reddish brown, streak brownish red. B.B. yields sulphur, after roasting reaction for manganese.

ALABANDITE, p. 206. H. = 3·5–4; G. = 4; submetallic, iron-black; streak green; B.B. on coal sulphur, after roasting reaction for manganese.

Vesuvianite, epidote, axinite, ilvaite, göthite, include varieties that give reaction for manganese.

IV. MINERALS OF METALLIC OR SUBMETALLIC LUSTRE NOT INCLUDED IN PRECEDING DIVISIONS.

1. YIELDING FUMES IN THE OPEN TUBE OR ON COAL, BUT NOT WHOLLY VAPORIZABLE.

A. STREAK METALLIC; H. = 1–2.

MOLYBDENITE, p. 108. H. = 1–1·5; G. = 4·4–4·8; lead-gray, and leaves trace on paper; B.B. on coal sulphurous fumes.

BISMUTHINITE, p. 114. H. = 2; G. = 6·4–7·2; lead-gray, whitish; B.B. on coal sulphurous fumes, and yellow bismuth oxide; sol. in hot nitric acid and a white precip. on diluting with water.

B. STREAK UNMETALLIC.

a. FUMES SULPHUROUS ONLY.

PYRITE, p. 192. H. = 6–6·5; G. = 4·8–5·2; isometric, most common in cubes, the faces of which sometimes smooth, often striated, the striæ of adjoining faces meeting at right angles, often in pyritohedrons; pale brass-yellow, streak gnh black, bnh black; B.B. on coal, fuses to a magnetic globule.

MARCASITE, p. 191. H. = 6–6·5; G. = 4.68–4·85; orthorhombic; pale bronze-yellow; streak gyh black, bnh black; B.B. like pyrite.

PYRRHOTITE, p. 192. H. = 3·5–4·5; G. = 4·4–4·68; hexagonal; bronze-yellow, rdh; streak gyh black; slightly magnetic; B.B. fuses to a magnetic mass.

MILLERITE, p. 181. H. = 3–3·5; G. = 4·6–5·7; rhombohedral, usually in acicular or capillary forms, also in fibrous crusts; brass-yellow, somewhat bronze-like; B.B. fuses to a globule, reacts for nickel.

LINNÆITE, p. 181. H. = 5·5; G. = 4·8–5; isometric; pale steel-gray, copper-red tarnish; streak blackish-gray; B.B. on coal fuses to a magnetic globule, after roasting gives reactions for nickel, cobalt, and iron.

SPHALERITE, p. 170. H. = 3·5–4; G. = 3·9–4·2; isometric; bright and easy dodecahedral cleavage when cryst.; lustre submetallic; color black; streak nearly uncolored; nearly infusible alone and with borax; on coal a coating of zinc oxide.

b. ARSENICAL FUMES, WITH OR WITHOUT SULPHUROUS.

ARSENOPYRITE, p. 192. H. = 5–6; G. = 6–6·4; orthorhombic; white, gyh, streak dark gyh black. In closed tube, red arsenic

sulphide and metallic arsenic; B.B. on coal fuses to magnetic globule.

GERSDORFFITE, p. 183. H. = 5·5; G. = 5·6–6·9; isometric, pyritohedral; white, gyh, streak grayish black. In closed tube arsenic sulphide, on coal not magnetic, and reacts for nickel and often cobalt.

NICCOLITE, p. 182. H. = 5–5·5; G. = 7·3–7·7; hexagonal; pale copper-red, streak pale bnh black; in open tube, coating of arsenous acid; B.B. on coal no sulph. fumes, fuses to globule which reacts for iron, cobalt and nickel.

SMALTITE, p. 181. H. = 5·5–6; G. = 6·4–7·2; isometric; tin-white; streak gyh black; on coal, no fumes of sulphur or only in traces.

2. NOT YIELDING FUMES OF ANY KIND. STREAK UNMETALLIC.

A. B.B. EASILY FUSIBLE, AND GIVING A MAGNETIC BEAD. LUSTRE SUBMETALLIC.

ILVAITE, p. 285. H. = 5·5–6; G. = 3·7–4·2; orthorhombic; gyh iron-black, streak gnh or bnh black; gelat. with HCl.

ALLANITE, p. 284. H. = 5·5–6; G. = 3–4·2; monoclinic; bnh pitch-black, streak gyh, bnh; B.B. fuses easily; most varieties gelat. with HCl.

WOLFRAMITE, p. 200. H. = 5–5·5; G. = 7·1–7·6; monoclinic; gyh black or bnh black; B.B. fuses easily, and reacts for iron, manganese, and tungsten.

B. INFUSIBLE OR NEARLY SO.

a. REACTION FOR IRON; ANHYDROUS; H. = 5–6·5.

MAGNETITE, p. 196. G. = 4·9–5·2; isometric; iron-black; streak black; strongly magnetic.

MENACCANITE, p. 195. G. = 4·5–5; rhombohedral; iron-black; streak submetallic, black to bnh red; very slightly magnetic.

HEMATITE, p. 193. G. = 4·5–5·3; rhombohedral; gyh iron-black, in very thin splinters or scales blood-red by transmitted light; streak red; sometimes slightly magnetic.

MARTITE, p. 194. Same as hematite, but isometric.

TANTALITE, p. 202. G. = 7–8; orthorhombic; iron-black, streak rdh brown to black.

FRANKLINITE, p. 197. H. = 5·5–6·5; G. = 4·8–5·1; octahedral, massive; iron-black; streak dark rdh brown; slightly attracted by magnet; with soda reaction for manganese.

COLUMBITE, p. 207. G. = 5·4–6·5; orthorhombic; iron-black, gyh black, streak dark red to black, often with a bluish steel-like tarnish.

SAMARSKITE, p. 221. H. = 5·5–7; G. = 5·6–5·8; velvet-black, pitch-black; streak dark rdh brown; B.B. glows; fuses with difficulty.

b. REACTION FOR IRON; HYDROUS; LUSTRE SUBMETALLIC.

LIMONITE, p. 198. G. = 3·6–4; not in crystals; massive, often stalactitic and tuberose with surface sometimes highly lustrous; often subfibrous in structure; black, bnh black; streak bnh yellow, which becomes red on heating.
GOTHITE, p. 199. G. = 4·0–4·4; orthorhombic; also fibrous and massive; bkh brown; streak bnh yellow.
TURGITE, p. 199. G. = 3·6–4·68; fibrous and massive, looking like limonite; black, rdh black, streak red; in closed tube decrepitates, which is not the case with göthite and limonite.

c. REACTION FOR CHROMIUM OR TITANIUM.

CHROMITE, p. 197. H. = 5–5; G. = 4·3–4·6; isometric; submetallic; bnh iron-black, streak brown; B.B. with borax gives a bead which on cooling is chrome-green.
RUTILE, p. 179. H. = 6–6·5; G. = 4·18–4·25; black, streak bnh; reacts for titanium. Black varieties of *brookite* (p. 180), submetallic in lustre, give same reaction.

Euxenite, p. 222; *yttrotantalite*, p. 221; *æschynite*, p. 222; *fergusonite*, p. 221; and *perofskite*, p. 180, are submetallic in lustre.

d. HEATED WITH NITRE IN A MATRASS YIELDS FUMES OF OSMIUM.

IRIDOSMINE, p. 141. H. = 6–7; G. = 19–21·2; in small scales from auriferous or platiniferous sands; tin-white, gyh.

V. LUSTRE UNMETALLIC.

1. MINERALS HAVING AN ACID, ALKALINE, ALUM-LIKE, OR STYPTIC TASTE.

A. CARBONATES: Taste alkaline; effervescing with HCl.

NATRON, p. 249. Effloresces on exposure.
TRONA, p. 249. Does not effloresce.

B. SULPHATES: No effervescence; reaction B.B. on coal with soda for sulphur.

MASCAGNITE, p. 250. Yields ammonia.
MIRABILITE, p. 246. Monoclinic, crystals stout; taste cool, saline, bitter; B.B. flame deep yellow.
EPSOMITE, p. 224. Orthorhombic, crystals ordinarily slender, spicule-like; taste bitter and saline; B.B. flame not yellow.
ALUNOGEN, p. 216. Taste like common alum.
KALINITE, MENDOZITE and other alums, p. 217.
MELANTERITE, p. 199. Green; taste styptic; reacts for iron.
CHALCANTHITE, p. 152. Blue; reacts for copper.

MORENOSITE, p. 185. Green; reacts for nickel.
BIEBERITE, p. 185. Reddish; reacts for cobalt.
GOSLARITE, p. 172. White; reacts for zinc.
JOHANNITE, p. 188. Emerald-green, reacts for uranium.

C. NITRATES: With sulphuric acid, reddish acrid fumes; no action with hydrochloric acid; deflagrate.

NITRE, p. 247. Not efflorescent. Strong deflagration.
NITRATINE, SODA-NITRE, p. 248. Efflorescent.
NITROCALCITE, p. 234. Deflagration slight.

D. CHLORIDES: With sulphuric acid acrid fumes of HCl; no fumes with HCl.

SALMIAK, p. 249. Taste saline, pungent; on coal, evaporates; with soda, odor of ammonia.
SYLVITE, p. 243. Taste saline; B.B. flame purplish.
HALITE or **COMMON SALT**, p. 243. Taste saline; B.B. flame yellow.

E. BORATES. No effervescence with acids; B.B. reaction for boron, when moistened with sulphuric acid.

SASSOLITE, p. 109. Taste feebly acid; B.B. very fusible.
BORAX, p. 246. Taste sweetish alkaline; B.B. puffs up.

2. MINERALS NOT HAVING AN ACID, ALKALINE, ALUM-LIKE OR STYPTIC TASTE.

A. CARBONATES: Effervescing with HCl.

A. INFUSIBLE; ASSAY ALKALINE AFTER IGNITION.

CALCITE, p. 234. H. under 3·5; G. = 2·5–2.72; $R \wedge R = 105° 5'$, with three easy cleavages parallel to R; colors various; effervesces readily with cold HCl; anhydrous.
ARAGONITE, p. 237. H. = 3·5–4; G. = 2·94; orthorhombic, cleavage imperfect; otherwise like calcite.
DOLOMITE, p. 238. H. = 3·5–4; G. = 2·8–2·9; rhombohedral, $R \wedge R = 106° 15'$; colors various; effervesces but slightly with *cold* HCl, unless finely pulverized; anhydrous.
MAGNESITE, p. 226. H. = 3·5–4·5; G. = 3–3·1; rhombohedral, $R \wedge R = 107° 29'$; white, ywh, gyh; effervesces but slightly with cold HCl; anhydrous.
HYDROMAGNESITE, p. 224. H. = 1–3·5; G. = 2·14–2·18; hydrous.

B. INFUSIBLE; BECOME MAGNETIC AND NOT ALKALINE AFTER IGNITION.

SIDERITE, p. 203. H. = 3·5–4·5; G. = 3·7–3·9; rhombohedral, $R:R = 107°$; cleavage as in calcite; becomes brown on exposure, changing to limonite.

ANKERITE, p. 204. H. = 3·5–4; G. = 2·9–3·1; $R \wedge R = 106° 7'$; becomes brown on exposure.

Some kinds of *calcite* and *dolomite* contain iron enough to become magnetic on ignition.

C. INFUSIBLE; B.B. ON COAL WITH SODA, COATING OF ZINC OXIDE.

SMITHSONITE, p. 172. H. = 5; G. = 4–4·5; rhombohedral like calcite; $R \wedge R = 107° 40'$; crystals often an acute rhombohedron; anhydrous.

HYDROZINCITE, p. 173. H. = 2–2·5; G. = 3·6–3·8; white, gyh, ywh, often earthy; reacts for zinc; hydrous.

D. INFUSIBLE; B.B. ON COAL REACTION FOR NICKEL.

ZARATITE (Emerald nickel), p. 185. H. = 3. Emerald green, streak paler.

E. FUSIBLE; ASSAY ALKALINE AFTER IGNITION.

WITHERITE, p. 241. H. = 3–3·75; G. = 4·29–4·35; orthorhombic; white, ywh, gyh; B.B. fuses easily, flame ywh green; anhydrous.

STRONTIANITE, p. 242. H. = 3·5–4; G. = 3·6–3·72; orthorhombic; pale green, gray, ywh, white; B.B. fuses only on thin edges, flame bright red; anhydrous.

BARYTOCALCITE, p. 242. Monoclinic. G. = 3·6–3·66; B.B. nearly like witherite.

Other carbonates are the Lead Carbonate, p. 168, and Copper Carbonates, p. 154, 156, included severally under the heads of LEAD and COPPER, on pages 416, 417.

B. SULPHATES or SULPHIDES: Reaction for Sulphur with Soda.

A. FUSIBLE; ASSAY ALKALINE AFTER FUSION.

BARITE, p. 240. H. = 2·5–3·5; G. = 4·3–4·72; orthorhombic; white, ywh, gyh, bluish, brown; B.B. decrepitates and fuses; flame yellowish green; anhydrous.

CELESTITE, p. 242. H. = 3–3·5; G. = 3·9–3·98; orthorhombic; white, pale blue, rdh; B.B. fuses; flame red; anhydrous.

ANHYDRITE, p. 230. H. = 3–3·5; G. = 2.9–3·0; orthorhombic, with three rectangular and easy cleavages differing but slightly; white, bluish, gyh, rdh, red; B.B. fuses, flame reddish yellow.

GYPSUM, p. 229. H. = 1·5–2; G. = 2·3–2·35; monoclinic, one perfect, pearly cleavage; white, gray, but also brown, black from

impurities; B.B. yields much water, becomes white and crumbles easily.

B. FUSIBLE; REACTION FOR IRON.

COPIAPITE, p. 200. H. = 1·5; G. = 2·14; yellow; on coal, becomes magnetic; hydrous.

Haüynite, p. 294, also gives the sulphur reaction with soda.

C. INFUSIBLE, OR NEARLY SO.

ALUMINITE, p. 218. H. = 1–2; G. = 1·66; adheres to the tongue; white; B.B. blue with cobalt solution. **Alunite**, p. 198, is similar, but H. = 4, and G. = 2·58–2·75.

SPHALERITE, p. 170. H. = 3·5–4; G. = 3·9–4·2; isometric, easy dodecahedral cleavage when cryst.; light to dark resin-yellow and brown to gyh white; B.B. on coal, coating of zinc oxide.

C. ARSENATES: Arsenical fumes on coal.

SCORODITE, p. 203. H. = 3·5–4; G. = 3·1–3·3; orthorhombic; leek-green to liver-brown; B.B. fuses easily, flame blue, and with soda gives a magnetic bead; on coal alliaceous fumes; in HCl sol.

PHARMACOSIDERITE, p. 203. H. = 2·5; G. = 2·9–3; cubes and tetrahedrons; dark green, bnh, reddish; B.B. same as for scorodite.

PHARMACOLITE, p. 234. H. = 2–2·5; G. = 2·6–2·75; wh, gyh, rdh; monoclinic with one eminent cleavage; B.B. fuses, flame blue; on coal, alliaceous fumes; after ignition assay alkaline; in HCl sol.

D. SILICATES, PHOSPHATES, OXIDES: SPECIES NOT INCLUDED IN THE THREE PRECEDING SUBDIVISIONS.

I. Streak deep red, yellow, brownish yellow, green or black.

A. INFUSIBLE, OR FUSIBLE WITH MUCH DIFFICULTY.

HEMATITE, p. 193. Rhombohedral; red to black; streak red; B.B. reaction for iron; magnetic after ignition in R.F.; anhydrous.

LIMONITE, p. 198. Brownish and ochre-yellow to black; streak brownish-yellow; B.B. gives off water, turns red, becomes magnetic in R.F.

TURGITE, p. 199. Brown to black; streak red; B.B. gives off water; decrepitates; becomes magnetic in R.F.

FERGUSONITE, p. 221. Brownish black; infusible.

ZINCITE, p. 171. Red; streak orange; B.B. on coal, zinc oxide coating, and coating moistened with cobalt solution, green in R.F.

B. FUSIBLE WITHOUT MUCH DIFFICULTY.

WOLFRAMITE, p. 200. Grayish to brownish black; streak dark reddish brown to black; lustre submetallic; G. = 7·1–7·55. B.B. fuses easily, and becomes magnetic; reaction for tungsten.

VIVIANITE, p. 202. Blue to green (to white); streak bluish white; G. = 2·5–2·7; H. = 1·5–2, hydrous; B.B. fuses easily to magnetic globule, coloring flame bluish green.

TORBERNITE, p. 187. Bright green, square tabular micaceous crystals; streak paler green; H. = 2–2·5; hydrous; yields a globule of copper with soda.

SAMARSKITE, p. 221. H. = 5·5–6; G. = 5·6–5·8; velvet-black; streak dark reddish brown; B.B. fuses on the edges.

II. Streak grayish or not colored.

1. INFUSIBLE.

A. GELATINIZE WITH ACID, FORMING A STIFF JELLY.

CHRYSOLITE, p. 277. Yellow-green to olive-green, looking like glass; H. = 6·7; G. = 3·3–3·5; B.B. reacts for iron, becomes magnetic; anhydrous.

CHONDRODITE, p. 303. H. = 6–6·5; G = 3·1–3·25; pale yellow to brown, and garnet-red; lustre vitreous to resinous; B.B. reaction for iron and fluorine; anhydrous.

ALLOPHANE, p. 318. H. = 3; G. = 1·8–1·9; always amorphous, never granular in texture; bluish, greenish; B.B. infus., a blue color with cobalt solution; hydrous.

Willemite, *Calamine*, *Sepiolite*, fuse with great difficulty, and are included under fusible gelatinizing species, pp. 428, 429.

B. NOT FORMING A STIFF JELLY WITH ACID; HYDROUS.

a. **Blue with cobalt solution** (owing to presence of aluminium).

WAVELLITE, p. 220. H. = 3·25–4; G. = 2·3–2·4; white to green, brown; B.B. bluish green flame after moistening with sulph. acid.

LAZULITE, p. 218. H. = 5·6; G. = 3–3·1; blue; B.B. green flame, especially after moistening with sulph. acid; hydrous.

TURQUOIS, p. 219. H. = 6; G. = 2·6–2·85; sky-blue, pale green; B.B. flame green.

KAOLINITE, p. 232. H. = 1–2; G. = 2·4–2·65; white when pure; feel greasy; B.B. flame not green.

GIBBSITE, p. 213. H. = 2·5–3·5; G. = 2·3–2·4; white, grayish, greenish; B.B. flame not green; soluble in strong sulph. acid.

DIASPORE, p. 213. H. = 6·5–7; G. = 3·3–3·5; in thin foliated crystals, plates or scales; white, greenish, brownish; B.B. flame not green; soluble in sulphuric acid *after* ignition.

b. **Pale red or pink color, with cobalt solution** (owing to presence of magnesium).

BRUCITE, p. 223. H. = 2·5; G. = 2·3–2·45; pearly, white, greenish; foliaceous or fibrous and flexible; B.B. after ignition, alkaline.

c. **Not blue or red with cobalt solution.**

OPAL, p. 259. H. = 5·5–6·5; G. = 1·9–2·3; B.B. with soda soluble with effervescence.

GENTHITE, p. 332. H. = 3–4; G. = 2·4; pale green, yellowish; B.B. with borax a violet bead, becoming gray in R.F. owing to nickel; decomp. by HCl.

CHRYSOCOLLA, p. 157. H. = 2–4; G. = 2–2·24; pale bluish green to sky-blue; B.B. flame emerald-green, and with soda on coal globule of copper.

The micas, chlorites, chloritoid, and serpentine often fuse on their edges with *much* difficulty.

C. NOT FORMING A STIFF JELLY; ANHYDROUS. H. = 5 to 9.

a. **Blue color with cobalt solution.**

CORUNDUM, p. 211. H. = 9; G. = 4; rhombohedral; blue, white, red, gray, brown.

CHRYSOBERYL, p. 215. H. = 8·5; G. = 3·7; orthorhombic; grayish green, to emerald-green, brown.

TOPAZ, p. 309. H. = 8; G. = 3·5; in rhombic prisms with perfect basal cleavage, rarely columnar; white, wine-yellow, and other shades.

RUBELLITE, p. 305; H. = 7·5; G. = 3; in prisms of 3, 6, or 9 sides; rose-red; reaction for boron.

ANDALUSITE, p. 306. H. = 7·5; G. = 3·2; orthorhombic; always in prismatic crystals, often tessellated within, $I \wedge I = 93°$; grayish white to brown.

FIBROLITE, p. 307. H. = 6–7; G. = 3·2; orthorhombic columnar or fibrous forms and prismatic crystals with brilliant diag. cleavage.

CYANITE, p. 308. H. = 5–7 (greatest on extremities of crystals); G. = 3·6; in long or short prismatic triclinic crystallizations, often bladed prisms; pale blue to white and gray.

LEUCITE, p. 295. H. = 5·5–6; G. = 2·5; often in trapezohedral crystals; white, gyh.

b. **Not giving a blue or reddish color with cobalt solution; H. = 8 to 5.**

SPINEL, p. 213. H. = 8; G. = 3·5–4·1; in octahedrons of red, greenish, gray, black colors; sometimes dodecahedral. *Gahnite* is similar, but with borax on coal, gives reaction for zinc.

BERYL, p. 274. H. = 7·5–8; G. = 2·6–2·7; always in hexagonal prisms; pale bluish and yellowish green to emerald-green, also resin yellow and white, no distinct cleavage.

ZIRCON, p. 281. H. = 7·5; G. = 4–4·75; tetragonal, and often in square prisms; lustre adamantine; brown, gray.

STAUROLITE, p. 291. H. = 7; G. = 3·4–3·8; in prisms of 123°, and often in cruciform twins; no distinct cleavage; brown, black, gray.

QUARTZ, p. 253. H. = 7; G. = 2·6; often in hexagonal crystals with pyramidal terminations; of various shades of color. OPAL, p. 259, is in part anhydrous.

MONAZITE, p. 222. H. = 5–5·5; G. = 4·9–5·3; in small brown imbedded monoclinic crystals, with perfect basal cleavage; B.B. flame bluish green when moistened with sulph. acid.

RUTILE, p. 179. H. = 6–6·5; G. = 4·15–4·25; tetragonal; reddish brown to brownish red, green, black; B.B. reaction for titanium. BROOKITE and OCTAHEDRITE, p. 180, are similar, except in crystalline forms, and G. in brookite 4·0–4·25, in octahedrite 3·8–3·95.

PEROFSKITE, p. 180. H. = 5·5; G. = 4–4·1; yellowish, brown, black; cubic and octahedral forms; B.B. reaction for titanic acid.

ENSTATITE, p. 264. H. = 5·5; G. = 3·1–3·3; in orthorhombic prismatic and fibrous forms with $I \wedge I = 88° 16'$, also foliated; whitish, grayish, brown, *bronzite* and *hypersthene* contain iron. *Anthophyllite* is similar, but $I \wedge I = 125°$, and it fuses on the edges with great difficulty.

Iolite, apatite, scheelite, euclase, fuse with much difficulty, and euclase gives some water in closed tube when highly ignited.

2. FUSIBLE WITH LITTLE OR MUCH DIFFICULTY.

A. Gelatinize and afford a Stiff Jelly.

a. Hydrous; fuse easily.

DATOLITE, p. 311. H. = 5–5·5; G. = 2·8–3; monoclinic; white, greenish, yellowish; crystals glassy, stout, sometimes massive and porcellanous, never fibrous; B.B. fuses easily, reaction for boron.

NATROLITE, p. 321. H. = 5–5·5; G. = 2·3–2·4; in slender rhombic prisms, and divergent columnar; white, ywh, rdh, red; B.B. fuses very easily.

SCOLECITE, p. 321. H. = 5–5·5; G. = 2·16–2·4; cryst. much like natrolite, but twinned, with converging striæ on i-$\bar{i}$ as in figure on p. 299; B.B. sometimes curls up, fuses very easily.

GMELINITE, p. 323. H. = 4·5; G. = 2–2·2; in small and short hexagonal or rhombohedral cryst.; B.B. fuses easily.

PHILIPPSITE, p. 324. H. = 4–4·5; G. = 2·2; in twinned crystals; B.B. fuses rather easily.

LAUMONTITE, p. 315. H. = 3·5–4; G. = 2·2–2·4; white, reddish; crystals become white and crumbling on exposure to the air; B.B. fuses rather easily.

Pectolite (p. 315) and *Analcite* (p. 322) imperfectly gelatinize.

b. Hydrous; fuse with much difficulty.

CALAMINE, p. 174. H. = 4·5–5; G. = 3·15–3·19; white, greenish, bluish; orthorhombic in crystals; B.B. fus. with great difficulty, reaction for zinc and none for iron; hydrous.

SEPIOLITE, p. 328. White; soft and almost clay-like, also fibrous; B.B. fuses with difficulty, with cobalt solution reddish; hydrous.

PYROSCLERITE, p. 338. H. = 3; G. = 2·74; micaceous; B.B. fuses on thin edges.

c. Anhydrous.

α. No reaction for sulphur; no coating on coal.

NEPHELITE, p. 293. H. = 5·5–6; G. = 2·5–2·65; hexagonal prisms and massive; vitreous, with greasy lustre; white, ywh, gyh brown, rdh; B.B. fuses rather easily.

WOLLASTONITE, p. 265. H. = 4·5–5; G. = 2·75–2·9; white, gyh, rdh, bnh; B.B. fuses easily.

SODALITE, p. 294. H. = 5·5–6; G. = 2·13–2·4; white, blue, reddish; in dodecahedrons and massive; B.B. fuses not very easily.

WILLEMITE, p. 173. H. = 5·5; G. = 3·9–4·3; white to greenish, reddish, brownish; B.B. glows and fuses with difficulty; reaction for zinc and none for iron; anhydrous.

β. Reaction for sulphur B.B. with soda.

HAUYNITE, p. 294. H. = 5·5–6; G. = 2·4–2·5; blue, greenish; isometric, in dodecahedrons, octahedrons; B.B. fuses with some difficulty.

DANALITE, p. 278. H. = 5·5–6; G. = 3·427; isometric; flesh-red to gray; B.B. fuses rather easily, and gives reaction for manganese and zinc.

B. Not Gelatinizing.

1. Structure eminently micaceous, surface of folia more or less pearly; H. of surface of folia not over 3·5; anhydrous or hydrous.

MUSCOVITE, BIOTITE, PHLOGOPITE, LEPIDOLITE, LEPIDOMELANE: for distinctions see pp. 287–291. Anhydrous, or affording very little water; B.B. fuse with difficulty on thin edges, excepting lepidomelane, which fuses rather more easily.

MARGARODITE, DAMOURITE, pp. 290, 335. Much like common mica, but more pearly and greasy to the feel, folia not elastic; giving a little water in the closed tube; color usually whitish.

PENNINITE, RIPIDOLITE, PROCHLORITE, p. 339. Usually bright or deep green, blackish green, reddish, rarely white; folia tough, inelastic; B.B. diff. fus., reaction for iron and yield much water; partially decomposed by acids.

VERMICULITE, JEFFERISITE, pp. 338, 339. Brown, yellowish brown, green; exfoliate remarkably; yield much water.

MARGARITE, p. 341. H. = 3·5–4·5 (highest on edges); G. = 2·99; white, ywh, rdh; folia somewhat brittle; B.B. fuses on thin edges; yields a little water.

TALC, p. 326. H. = 1–1·5; G. = 2·5–2·8; pearly and very greasy to the touch; white pale green, gray; B.B. very difficultly fusible, yields usually traces of water; reddish with cobalt solution.

PYROPHYLLITE, p. 328. Similar to talc; but B.B. exfoliates remarkably; blue with cobalt solution.

FAHLUNITE, p. 336, has often a more or less distinct micaceous structure.

Autunite, p. 188, has a mica-like basal cleavage; but it occurs in small square tables of a bright yellow color. *Diallage*, p. 267, has a structure nearly micaceous. *Serpentine* is sometimes nearly micaceous, but the folia are not easily separable and are brittle. *Chloritoid* has a perfect basal cleavage, but folia very brittle, and cleavage less easily obtained than in the preceding; and moreover the mineral is infusible.

2. Structure not micaceous.

a. Hydrous.

α. No reaction for phosphorus, or boron.

† Hardness, with the exception of a variety of serpentine, 1 to 3; lustre not at all vitreous.

CHLORITES, p. 337. H. = 2–2·5. Here fall the massive granular chlorites, olive-green to black in color, of the species *penninite, ripidolite, prochlorite;* B.B. reaction for iron, fuses with difficulty; yields much water.

VERMICULITE, p. 338. H. = 1–1·5. Granular massive forms of vermiculite.

TALC, p. 326. H. = 1–1·5. Here falls steatite (soapstone) or massive talc, of white to grayish green and dark green color, granular to cryptocrystalline in texture. B.B. fuses with great difficulty, and yields only traces of water; no reaction for iron, or only slight.

PYROPHYLLITE, p. 328. Grayish white, massive or slaty; B.B. like the crystallized in its difficult fusibility and little water yielded, but does not exfoliate.

SERPENTINE, p. 329. H. = 2·5–4; G. = 2·36–2·55; olive-green; ywh green; blackish green, white; B.B. fuses with difficulty on thin edges; yields much water.

PINITE, p. 334. H. = 2·5–3·5; G. = 2·6–2·85; lustre feebly waxy; gray, gnh, bnh. B.B. fuses; yields water.

DAMOURITE, p. 335. Same as crystallized, p. 403, but in massive aggregation of scales.

†† Hardness 3·5 to 6·5; lustre often pearly on a cleavage surface, but elsewhere vitreous.

PREHNITE, p. 317. H. = 6–6·5; G. = 2·8–3; pale green to white; crystals often barrel-shaped, made of grouped tables; B.B. fuses very easily; decomp. by HCl.

PECTOLITE, p. 315. H. = 5; G. = 2·68–2·8; white; divergent fibrous, or acicular; B.B. fuses very easily; gelatinizes imperfectly with HCl.

APOPHYLLITE, p. 316. H. = 4·5–5; G. = 2·3–2·4; white, gnh, ywh, rdh; tetragonal, one perfect pearly cleavage transverse to prism; B.B. fuses very easily; a fluorine reaction; decomp. by HCl.

CHABAZITE, p. 322. H. = 4–5; G. = 2–2·2; rhombohedral, vitreous; white, rdh; B.B. fuses easily; decomp. by HCl.

HARMOTOME, p. 323. H. = 4·5; G. = 2·44; white, ywh, rdh; crystals twins, usually cruciform; B.B. fuses not very easily; vitreous in lustre; decomp. by HCl.

STILBITE, p. 324. H. = 3·5–4; G. = 2–2·2; white, ywh, red; crystal-

lizations often radiated-lamellar; one perfect pearly cleavage; B.B. exfoliates, fuses easily; decomp. by HCl.

HEULANDITE, p. 325. H. = 3·5–4; G. = 2·2; in oblique crystals, with one perfect pearly cleavage; B.B. same as for stilbite.

EUCLASE, p. 311. H. = 7–5; G. = 3·1; in glassy transparent monoclinic crystals; B.B. fuses with great difficulty; gives water in closed tube *when strongly ignited.*

Prehnite, apophyllite, chabazite, harmotome, heulandite, and *euclase* never occur in fibrous forms. *Epidote* and *zoisite* (p. 407), like euclase, give out water when strongly ignited.

β Reaction either for phosphorus or boron.

VIVIANITE, p. 203. H. = 1·5–2; G. = 2·55–7; monoclinic with one perfect cleavage; white, blue, green; B.B. fuses very easily, the flame bluish green, a gray magnetic globule; in HCl sol.

ULEXITE, p. 231. H. = 1; G. = 1·65; white, silky, in fine fibres; B.B. fuses very easily, and moistened with sulph. acid flame for an instant green, owing to the boron present; little sol. in hot water. Priceite (p. 212) is in texture and color like chalk; similar to ulexite in green flame B.B.

Borax and *Sassolite* are other soft minerals containing boron, but these have *taste.*

b. Anhydrous.

α. B.B. the flame lithium-red.

SPODUMENE, p. 269. H. = 6·5–7; G. = 3·13–3·19; white, gyh, gnh white, reddish, emerald-green, monoclinic (like pyroxene), with $I \wedge I = 87°$, and perfect cleavage parallel to *I* and *i-i;* B.B. swells and fuses.

PETALITE, p. 269. H. = 6–6·5; G. = 2·4–2·5; white, gray, rdh, gnh; B.B. becomes glassy and fuses only on the edges.

AMBLYGONITE, p. 218. H. = 6; G. = 3–3·1; mountain green, gyh, white, bnh; B.B. fuses very easily, reaction for fluorine.

TRIPHYLITE, p. 208. H. = 5; G. = 3·5–3·6; greenish gray, bluish, often bnh black externally; B.B. fuses very easily, globule magnetic; with soda, manganese reaction.

LEPIDOLITE, p. 289. H. = 2·5–4; G. = 2·8–3; micaceous, also scaly-granular; rose-red, pale violet, white, gyh; B.B. fuses easily; after fusion gelat. with HCl. Some *biotite*, p. 291, gives the lithia reaction.

β. B.B. boron reaction (green flame).

TOURMALINE, p. 304. H. = 7; G. = 2·9–3·3; rhombohedral, prisms with 3, 6, 9 sides, no longitudinal or other distinct cleavage; black, blue black, green, red, rarely white; lustre of dark var. resinous; B.B. fusion easy for dark var. and diff. for light.

AXINITE, p. 286. H. = 6·5–7; G. = 3·27; triclinic, sharp-edged, glassy crystals; rich brown to pale brown and grayish, B.B. fuses readily; with borax violet bead.

BORACITE, p. 225. H. = 7; G. = 2·97; isometric; white, gyh, gnh; lustre vitreous; fuses easily, coloring flame green.

Danburite, p. 286, is another boron silicate.

γ. Reaction for titanium.

TITANITE, p. 312. H. = 5–5·5; G. = 3·4–3·56; monoclinic; usually in thin sharp-edged crystals; brown, ywh, pale green, black; lustre usually subresinous; B.B. fuses with intumescence.

δ. Reaction for fluorine or phosphorus.

CRYOLITE, p. 216. H. = 2·5; G. = 2·9–3; white, rdh, bnh; *fuses in the flame of a candle;* soluble in sulph. acid which drives off hydrogen fluoride, a gas that corrodes glass.

FLUORITE, p. 227. H. = 4; G. = 3–3·25; isometric, with perfect octahedral cleavage, and massive; white, wine-yellow, green, purple, rose-red, and other bright tints; phosphoresces; when heated, decrepitates; B.B. fuses, coloring the flame red; after ignition, alkaline.

Lepidolite (p. 289), *Amblygonite* (p. 218), give a fluorine reaction.

APATITE, p. 232. H. = 4·5–5; G. = 2·9–3·25; often in hexagonal prisms; pale green, bluish, yellow, rdh, bnh, pale violet, white; B.B. fuses with difficulty, moistened with sulph. acid and heated, flame bluish green from presence of phosphorus; sometimes reaction for fluorine.

ε. Reaction for iron.

GARNET, p. 278. H. = 6·5–7·5; G. = 3·15–4·3; isometric, usually in dodecahedrons and trapezohedrons, also massive, never fibrous or columnar; red, bnh red, black, cinnamon-red, pale green to emerald-green, white. B.B. dark-colored varieties fuse easily, and give iron reaction, but emerald-green var. almost infusible; a white to yellow massive garnet is hardly determinable without chemical analysis.

VESUVIANITE (Idocrase), p. 282. H. = 6·5; G. = 3·35–3·45; tetragonal and often in prisms of four or eight sides, never fibrous; brown to pale green, ywh, bk; B.B. fuses more easily than garnet; reaction for iron.

EPIDOTE, p. 283. H. = 6–7; G. = 3·25–3·5; in monoclinic cryst. and massive, rarely fibrous; unlike amphibole in having but one cleavage direction; ywh green, bnh green, black, rdh, yellow, dark gray; B.B. fuses with intumescence; contains some water, but separated only at a high temperature.

AMPHIBOLE, dark varieties including *hornblende, actinolite*, and other green to gray and black kinds, p. 270. H. = 5·6; G. = 3–3·4; monoclinic, in short or long prisms, often long fibrous, lamellar, and massive, prisms usually four or six sides, $I \wedge I = 124\frac{1}{2}°$, cleavage par. to I; B.B. fusion easy to moderately difficult.

ANTHOPHYLLITE, p. 273, like hornblende, but orthorhombic; bnh gray to bnh green, sometimes lustre metalloidal; B.B. fuses with great difficulty.

PYROXENE, *augite*, and all green to black varieties, p. 265. H. = 5–6; G. = 3·2–3·5; monoclinic, in short or oblong prisms, lamellar, columnar, not often long, fibrous or asbestiform, prisms usually with four or eight sides, $I \wedge I = 87° 5'$, cleavage par. to I; B.B. as in hornblende.

HYPERSTHENE, p. 264. H. = 5–6; G. = 3·39; cryst. nearly as in pyroxene, but orthorhombic, usually foliated massive, also fibrous; bnh green, gyh black, pinchbeck-brown; B.B. fuses with more or less difficulty. *Bronzite*, p. 244, is similar and almost infusible.

IOLITE, p. 287. H. = 7–7·5, G. = 2·6–2·7; orthorhombic; blue to blue violet; looks like violet-blue glass; B.B. fuses with much difficulty.

Tourmaline, much *Titanite*, and *Ilvaite* (p. 285), B.B give iron reaction.

ζ. No reaction for iron.

SCHEELITE, p. 232. H. = 4·5–5; G. = 5·9–6·1; tetragonal; ywh, gnh, rdh, pale yellow; lustre vitreous-adamantine; fuses on the edges with great difficulty.

SCAPOLITES, p. 292. H. = 5·5–6; G. = 2·6–2·74; tetragonal, often in square prisms; white, gray, gnh gray; B.B. fuses easily with intumescence.

ZOISITE, p. 285. H. = 6–6·5; G. = 3 1–3·4; orthorhombic, oblong prisms and lamellar massive, cleavage in only one direction; like epidote in giving out some water when highly ignited.

AMFHIBOLE, *white var.* (*tremolite*), p. 270. Same as for other amphibole (above), except in color; B.B. fuses.

PYROXENE, *white var.*, p. 266. Same as for other pyroxene (above), except in color; B.B. fuses.

ORTHOCLASE, p. 300. H. = 6–6·5; G. = 2·4–2·62; monoclinic, stout cryst., and massive, never columnar, two unequal cleavages, the planes at right angles with one another, and cleavage surfaces never finely striated, as seen under a pocket lens or microscope; white, gray, flesh-red, bluish, green; B.B. fuses with some difficulty.

ALBITE, p. 299, **OLIGOCLASE**, p. 299. H. = 6; G. = 2·56–2·72, triclinic, but cryst. as in orthoclase, except that the two cleavage planes make an angle of 93½° to 94°, and one of them has the surface striated; white usually, flesh-red, bluish; B.B. fuse with a little difficulty; not acted on by acids.

LABRADORITE, p. 298. H. = 6; G. = 2·66–2·76; triclinic, like albite in cryst., and nearly in cleavage angle, 93° 20′, and in striæ of surface; white, flesh-red, bnh red, dark gray, gyh brown; B.B. fuses easily; decomposed by HCl with difficulty.

ANORTHITE, p. 298. H. = 6–7; G. = 2·66–2·78; cryst. and striæ as in albite, cleavage angle 94° 10′; white, gyh, rdh; B.B. fusion difficult; decomposed by HCl with separation of gelat. silica

MICROCLINE, p. 300. Very near orthoclase in all characters, but triclinic, cleavage angle differing only 16′ from a right angle, and surface of most perfect cleavage striated, but striæ exceedingly fine, often difficult to detect with a good pocket lens, and requiring the aid of a polariscope; color white, gray, flesh-red, often green.

For optical distinctions of FELDSPARS, see beyond.

EUCLASE, p. 311. H. = 7·5; G. = 3·1; in monoclinic crystals, with one perfect diagonal cleavage, pale green to white, bnh; transparent; becomes electric by friction.

ON ROCKS.—PETROLOGY.

THE term Petrology, signifying the science of Rocks, embraces the study of the origin and transformation of rocks, as well as their classification and distinctive characters. The last of these subjects alone is included under the term Petrography.

Rocks are made up of minerals. A few kinds consist of a single mineral alone: as, for example, *limestone*, which may be either the species calcite or dolomite; *quartzyte* (along with much sandstone), which is quartz; and *felsyte*, which is orthoclase. But even these simple kinds are seldom free from other ingredients, and often contain visibly other minerals. Nearly all kinds of rocks are combinations of two or more minerals. They are not definite compounds, but indefinite mixtures, and hardly less indefinite than the mud of a mud-flat. The limits between kinds of rocks are consequently ill-defined. Granite graduates insensibly into gneiss, and gneiss as insensibly into mica schist and quartzyte, syenyte into granite, mica schist into hornblende schist, granite also into a compact porphyry-like rock, and quartz-trachyte; and so it is with many other kinds. The fact is a chief source of the difficulty in studying and defining rocks, and especially the crystalline kinds. The different rocks are not *species* in the sense in which this word is used in science, but only *kinds* of rocks.

I. CONSTITUENTS OF ROCKS.

The following is a list of the chief constituent minerals and of the more important of the accessory species:

A. SILICEOUS SPECIES AND SILICATES.

1. Quartz, tridymite, opal.
2. The FELDSPARS: all NON-FERRIFEROUS; all ALKALINE (alkali-bearing, containing either potash or soda) except anorthite; *orthoclase*,

microcline, oligoclase, labradorite, the more abundant; *andesine, anorthite, albite,* and intermediate kinds, less so.

3. OTHER NON-FERRIFEROUS ALKALINE MINERALS: *leucite,* containing 17 to 21 p. c. of potash, with the atomic ratio that of andesine; *nephelite* (elæolite), 15 to 16 p. c. of soda with 5 or 6 of potash; *sodalite,* 20 to 25 p. c. of soda; *some scapolites,* 5 to 6 p. c. of soda; *spodumene,* about 5 p. c. of lithia.

4. OTHER NON-FERRIFEROUS ALKALINE MINERALS: THE SAUSSURITE-ZOISITE GROUP: light-colored, tough, jade-like minerals, derived (as shown by remains of crystalline forms and cleavage) from the alteration mainly of labradorite or anorthite, and in the change becoming of high specific gravity (3–3·4); contain 4 to 5 p. c. of alkali, nearly all of it soda, and 40 to 50 p. c. of silica. See on Saussurite, p. 285.

5. The MICAS: ALKALINE, AND CONTAINING MORE OR LESS IRON. Biotite is often styled *magnesia*-mica, although truly a *potash* mica like muscovite. Some muscovite, biotite, and other species contain lithia as well as potash. *Gieseckite* or *pinite* has the composition of a hydrous mica, but occurs only massive, and usually as a pseudomorph.

6. ALKALINE FERRIFEROUS SPECIES: *Acmite* and *ægirite,* near pyroxene in angle, 10 to 13 p. c. of soda; *arfvedsonite* and *glaucophane,* near hornblende, 5 to 9 p. c. of soda. A few analyses of ordinary hornblende give 1 to 4 p. c. of soda.

7. NON-ALKALINE FERRIFEROUS SPECIES: part of *amphibole* (hornblende, smaragdite), *pyroxene* (augite, diallage, etc.) and *garnet,* with *hypersthene, epidote, tourmaline, chrysolite, staurolite.*

8. NON-ALKALINE, NON-FERRIFEROUS SPECIES: *enstatite* (in part), *cyanite, andalusite, fibrolite* (sillimanite).

9. HYDROUS NON-ALKALINE SPECIES: *serpentine, talc, pyrophyllite, chlorite;* the first *two* magnesian, without iron or aluminium, except as impurity; the *third,* aluminous and talc-like, without iron or magnesium; the *fourth,* containing iron, mangesium, and aluminium.

Of these silicates, tourmaline is peculiar in containing 5 to 9 p. c. of *boron.*

B. CALCAREOUS, OR CARBONATES, SULPHATES, AND PHOSPHATES OF LIME.

Calcite, dolomite, aragonite, gypsum, anhydrite, apatite.—Aragonite is a large constituent of common uncrystalline limestones, for this form of calcium carbonate enters into the constitution of many shells and some other organic secretions, out of which limestones have to a great extent been made. Apatite, or calcium phosphate, occurs in beds and veins in large crystallizations; but is of especial interest petrologically because distributed sparingly in microscopic crystals through most igneous and metamorphic rocks.

C. IRON OXIDES AND SULPHIDES.

Hematite, magnetite, menaccanite, pyrite, pyrrhotite, marcasite.—The oxides constitute beds; in microscopic grains all are very common in basic igneous rocks and in many metamorphic rocks.

Of the above-named silicates the prominent constituents of the common rocks include about twenty. These are: *orthoclase, microcline, oligoclase, andesine, labradorite, anorthite, muscovite, biotite, hydrous micas; nephelite* (the massive form of which is called *elæolite*), *leucite; hornblende, pyroxene* (*augite*), *hypersthene; chrysolite, serpentine,* and two or three species of *chlorite.*

a. Arrangement of the enumerated species according to the proportion of silica, or the acidic constituent, in the mineral.

1. The eminently *acidic species.* Orthoclase (having about 65 p. c. of silica), albite (about 67), oligoclase (about 60), spodumene (about 64), talc (about 62).

2. *Sub-acidic species.* Andesine (about 58 p. c.), leucite (about 56), dipyre among scapolites (about 56), glaucophane (55–58).

3. *Basic species.* Labradorite (mostly 50–54 p. c.), anorthite (about 44), nephelite (about 44), most scapolite with meionite (40–47), the micas (mostly 40 to 49), gieseckite (45–48); saussurites (40–50), zoisite (mostly 40–42); hornblende of black and dark colors (mostly 40–50, but the light green and white var., 55–60), arfvedsonite (49–51), pyroxene of black or dark colors (mostly 44–52, diallage 49–52, but light green and whitish pyroxene 52–56); hypersthene (50–53, but enstatite 54–57), ægirite (50–52, but acmite 51–55); serpentine (mostly 41–43 p. c.).

4. *Ultra-basic species.* Sodalite (with haüynite about 37 p. c.), epidote (mostly 36–38), zircon (32–34), garnet (34–40), chrysolite (mostly 36–40, but fayalite 29–30), tourmaline (mostly 36–40), andalusite (36–40), fibrolite (36–40), cyanite (36–40), topaz (mostly 33–35), staurolite (about 30), chlorite (mostly 25–34), chloritoid (ottrelite) (23–27 p. c.).

b. The distinction of acidic and *basic* is one easily used in the subdivision of rocks, but it is not necessarily that of greatest value as regards the nature and origin of rocks. That connected with the *kind of base* is in many cases more fundamental, and its use in conjunction with the former is to some extent required. The two influential groups in this respect are: the *alkaline,* characterized by the presence of potash and soda; and the *ferriferous,* having much iron and little or no alkali; the former low in specific gravity (mostly under 2·75), the latter high (over 2·75). Using

this characteristic, sodalite and nephelite may have a place with the potash and soda feldspars, where they belong; and the micas also, because of their potash.

The *acidic* character of a rock is enhanced by the presence of quartz (free silica). But the amount of quartz which may occur in any quartz-bearing rock varies from very little to much; and the same mineral constitution often occurs without quartz. Thus syenyte (hornblende and orthoclase), dioryte (hornblende and oligoclase), felsyte (orthoclase), trachyte (orthoclase), amphibolyte (hornblende), granite (orthoclase and mica), gabbro and diabase (augite and labradorite), etc., occur with and without quartz. Quartz is thrown about freely among eruptive as well as metamorphic and fragmental rocks, and its presence or not is a characteristic therefore of inferior value, although of geological interest. It is absent from augitic rocks more commonly than from hornblendic.

c. The *paramorphic relations* of certain of the mineral species, explained on page 61, have an important bearing on the relations and origin of some rocks. The difference in crystallization in paramorphs—for example, in pyroxene and hornblende—is an unstable difference, one of the two species lapsing readily, under certain conditions, into the other. Through paramorphism, therefore, two rocks may be different mineralogically while identical chemically, and by easy alteration become identical mineralogically.

The cases of paramorphism of greatest importance petrologically are the following: that of *pyroxene* and hornblende, of *hypersthene* and hornblende, and of *aragonite* and calcite; and, besides these, there are that of *andalusite* and cyanite, of *tridymite* and quartz, of *opal* and quartz, of *glass* and stone. The name of the least stable species in each case is here italicized. Further remarks on the alterations are made and illustrated beyond.

II. DISTINCTIONS AMONG ROCKS.

1. *Based on General Methods of Origin.*

The first and most obvious division among rocks is into (1) *Uncrystalline* and (2) *Crystalline.*

Uncrystalline rocks are made of the fragments of older rocks—that is, out of the sand, mud, clay, gravel, derived

from them through disintegration and decomposition; and they represent, but in a consolidated form, the sand-beds, gravel-beds, and mud-deposits of past time. They include also the limestones, which were made from the ground shells, corals, etc., of the same eras. They are therefore called *Fragmental* rocks; or, using a corresponding word adopted from the Greek (*klastos*, broken), *Clastic* rocks.

Crystalline rocks are made not of worn or broken grains like fragmental rocks, but of crystalline, as in marble and granite. There are three divisions of them: (1) *igneous* or *eruptive*, or those rocks which came up melted from depths below through fissures or through volcanic vents; (2) *metamorphic* rocks, or those that were made by metamorphism out of common limestones, common fragmental rocks, or out of older crystalline rocks; (3) *chemically deposited*, made by deposition from solution, like travertine (p. 236) from calcareous waters, and like the siliceous deposits from the geyser waters of Iceland, or of Yellowstone Park, etc.

Among eruptive and metamorphic crystalline rocks other distinctions are used, as follows.

2. *Based on Mineral Constitution.*

This is the criterion of chief importance. If a rock consists of two or more minerals, the two most characteristic are usually taken as the essential constituents, and the others are regarded as *qualifying* minerals distinguishing varieties, or else as *accessory* species. Quartz, because of its so universal distribution among rocks, is one of the less important ingredients, as observed above; it is the basis of quartz-bearing and quartzless kinds under most of the eruptive and metamorphic rocks.

In granite (consisting of quartz, feldspar, and mica), with its schistose variety, gneiss, the most strongly pronounced characteristic proceeds from the two potash-bearing constituents; it is the chief potash-bearing rock in the world's foundations. The second marked feature of granite is the "acidic" quality of the feldspar, orthoclase. The quartz serves only to heighten the acidic quality of the rock: it may be absent altogether, without affecting essentially its chemical or mineral nature. So it is in felsyte, syenyte, which are also among the acidic rocks: the quartz is the less essential and varying ingredient. Quartz occurs

occasionally among some basic labradorite rocks, but they are nevertheless *basic* rocks.

3. *Based on Variations in Crystalline Condition or Texture.*

The distinctions based on crystalline condition or texture speak strongly to the eye, and were formerly deemed of prominent importance.

a. Foliated or not.—This distinction has reference to the species hornblende and pyroxene. The foliated variety in each (called *smaragdite* in the former and *diallage* in the latter) has no chemical and small mineralogical importance, and recently it has been proved by Judd that it is usually a result of slight or incipient alteration.

b. Fine-grained or not.—The rocks granulyte, quartz-felsyte, and rhyolyte have essentially the same mineral composition, but differ in texture; and so also trachyte and the felsyte that is free from quartz; dioryte and andesyte; quartz-dioryte and dacyte; gabbro, diabase, doleryte, and basalt. The use of different names in such cases is often convenient, but the fundamental identity should not be overlooked. Degree of fineness or coarseness has depended chiefly on rate of cooling, the finer kinds resulting from relatively rapid cooling. The eruptive rock filling a large fissure, or a space opened between layers of a stratified rock, is often aphanitic in its outer portion, where it was rapidly cooled against cold walls, while coarse-grained within, where cooling was very slow. The same igneous mass has been found to be scoriaceous and aphanitic exteriorly, while granite-like inside, with gradations between: as in Nevada, where the Sutro tunnel gives a complete section four miles long (Hague & Iddings, 1885); in Ireland, where the rock of the same mass varies from euphotide having a granitoid texture in part, through diabase and doleryte to scoriaceous basalt and basalt-glass (J. W. Judd, 1885); in Italy, where other examples occur of the same transition from coarse and compact euphotide to basalt and basaltic glass (B. Lotti, 1886).

The cellules and scoriaceous character of an eruptive rock are due to the expansive action of suddenly produced vapor: the vapor usually of water; but sometimes of carbonic acid, or other vaporizable material. It is absent, therefore, at depths below, where the pressure was too great

to allow of vaporization. The cavities of an amygdaloid are similar in origin to those of a scoria. In the trap of the Connecticut valley these cavities are sometimes cylindrical, the diameter not greater than that of a pipe-stem, while two or three inches long; they were made (the author deems probable) by the sudden vaporization of minute drops of liquid carbonic acid.

c. Porphyritic or not.—When a constituent mineral is in defined crystals, and especially when that mineral is a feldspar, the rock is said to be *porphyritic* (Figs. 1 to 3). The *ground-mass* or *base* may be either fine or coarse in texture. The porphyry of the ancients has an aphanitic ground-mass, with thickly sprinkled feldspar crystals of lighter color. Fig. 1 represents the *red antique porphyry* of Egypt—now called *Rosso antico*—the rock which gave the name porphyry to geology, a kind much used by the

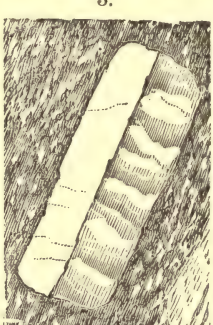
1.

Rosso Antico.

2

Oriental Verd-antique.

3.



Porphyritic gneiss.

Romans (though not by the Greeks or Egyptians), and quarried by them in the mountain Djebel-Dokhan, twenty-five miles from the Red Sea, in latitude 27° 20′. Figure 2 is from a polished piece of *green antique porphyry* from western Greece. The feldspar crystals are comparatively large, and the compact base has a dark green color. Figure 3 represents a large crystal of orthoclase in gneiss, from a *porphyritic gneiss*. The feldspar crystals in porphyritic gneiss or granite are sometimes over three inches long.

The orthoclase crystal in porphyritic rocks is often a Carlsbad twin (p. 301), the plane of cleavage of one half making an angle of 52° 23′ with that of the other half (Fig. 3).

Rocks are also said to be porphyritic when they contain augite (pyroxene), or quartz, or some other mineral disseminated through the mass in defined crystals; and the terms *orthophyre, augitophyre, quartzophyre,* and others similar in form, have thus originated. As various kinds of rocks may thus be orthophyres, etc., precision in describing them is obtained by making the word an adjective, and indicating, in each case, the kind of mineral that is porphyritically defined: thus, *augitophyric,* when the mineral is augite; *quartzophyric,* when quartz; *chrysophyric,* when chrysolite; *leucitophyric,* when leucite; *orthophyric,* when orthoclase; *oligophyric,* when oligoclase; *labradophyric,* when labradorite; *anorthophyric,* when anorthite; and so on.

Porphyritic rocks are often treated in petrology as if *porphyry* were a distinct *kind* of rock, or as if the porphyritic variety of a kind of rock merited special prominence. But, as recognized beyond, "felsyte-porphyry" is *porphyritic felsyte;* "dioryte-porphyry" is *porphyritic dioryte;* "diabase-porphyry" is *porphyritic diabase;* and, in these and other like cases, the being porphyritic is a characteristic of minor value. On the other hand, a *quartz porphyry,* as the term has been used, is not, consistently with the other kinds, porphyritic quartzyte; but, inconsistently, almost any rock except quartzyte, which contains disseminated quartz in defined crystals or grains; the name is doubly objectionable because, besides the above inconsistency, it covers rocks of various mineral constitution.

d. Glass and Stone; Microlites.—Besides the distinction of coarse and fine in texture among eruptive rocks, there is also that of *glass* and *stone.* All stages in the gradation from stone to glass exist, and few modern igneous rocks, and not all of the ancient, however stony they may appear to the eye, are wholly stone, or *holocrystalline,* as they are then termed (from the Greek *holos,* all, and crystalline). Glass is stony material that has been somewhat rapidly cooled from fusion; it is most common in connection with orthoclase lavas. A granite may be turned into glass by melting, and, if it has little quartz and no mica, into clear glass; and bottle-glass has been made out of some kinds of trap. Conversely, any glass, if subjected in a furnace to a bright red heat (short of the heat of fusion) for three or four weeks will pass more or less completely to the *lithoid*

or *stony* state—that is, become *devitrified*, or converted into stone. Part of the molecular difference of stone and glass is manifested in the inferior specific gravity of the latter. Thus in the case of—

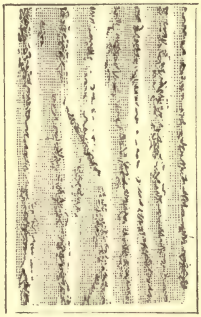
	As Stone.	As Glass.		As Stone.	As Glass.
Quartz.....G. =	2·65	2·19	Augite.....G. =	3·27	2·80
Orthoclase...	2·58	2·31	Chrysolite..	3·38	3·18
Labradorite..	2·73	2·57	Doleryte...	2·95	2·84
Hornblende..	3·21	2·82	Trachyte...	2·58	2·45

The names *pitchstone* and *pearlstone* are applied to some of the intermediate stages between stone and glass; and the name *obsidian*, to volcanic glass of trachytic or rhyolitic outflows; *tachylite*, to that of basaltic. Figures 4, 5 (from Zirkel), and 6 (from Rosenbusch) represent, much-magnified, transparent slices from glassy rocks in three of their stages; Fig. 4 of obsidian, containing radiating clusters of hair-like *microlites* (or microscopic minerals), called *trichites* (from the Greek *thrix*, hair), such as are common in all obsidians; Fig. 5, of pearlyte, a light-gray rock of

4.

Trichites in Obsidian.

5.



Trichites and Fluidal texture in Pearlyte.

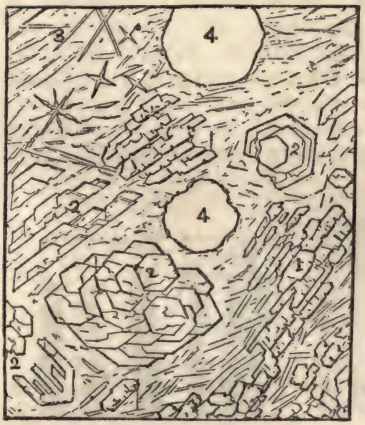
6.

Microlites in Pitchstone from Weissenberg.

pearly lustre from the Nevada Basin, having its trichite clusters very numerous, and arranged in lines or planes, and some of the trichites powdered with pellucid grains, or *globulites*, which are incipient crystals; Fig. 6, of pitchstone, from Weissenberg, in which the microlites are distinctly crystalline in form, and some give evidence that

they are feldspar crystals, others that they are augite and magnetite, and indicate that the rock is intermediate between a glass and a basalt. Thus there is a passage toward ordinary stone. The slags of furnaces are of the nature of an obsidian or a tachylite, or of some of the stages between it and stone; and they often illustrate igneous rocks in their microlitic and mineral structure. Figure 7 represents a section much enlarged of a slag found in the soil over which a stack of wheat-straw had been burned. The crystals No. 1 are melilite; 2, the mineral tridymite, (which occurs in cavities in the obsidians of the Yellowstone Park); 3, indeterminate acicular microlites; and 4, air-vesicles. Figure 8 is the same from a limekiln slag in France; and its minerals and aspect are those of a section of doleryte or basalt (as the author of the article, M. Ch. Vélain, observes): 1 being magnetite, 2 augite, and 3 labradorite in lath-shaped crystals. The cavities (4) in the latter are described as often coated with acicular crystals.

7.



Slag from the burning of a stack of wheat-straw.

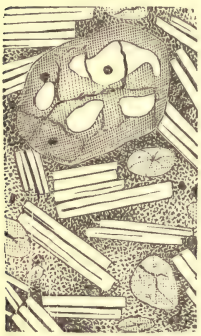
8.

Slag from a limekiln, basalt-like in composition.

Eruptive rocks, when looking as if stone throughout, often have glassy particles among the stony. If they have come up through a fissure, the part near the walls of the

fissure may contain particles of glass, and the interior of the mass none. Many igneous rocks have glassy grains among the stony grains, or a glassy *base*, because the cooling was not slow enough for complete *lapidification*. Such portions of a rock are described as *unindividualized*. An unindividualized base exists in the basalt of Truckee Valley, the character of a slice from which, highly magnified, is given in Fig. 9 (from Zirkel); here, feldspar crystals, of their usual lath-like forms (part of them sanidin), a largish crystal of chrysolite, and smaller irregularly shaped augites, are imbedded in a glassy base in which are extremely small globulite grains that are globules of devitrified glass or incipient crystals. The glassy unindividualized base occupies the spaces among the crystalline portions.

9.

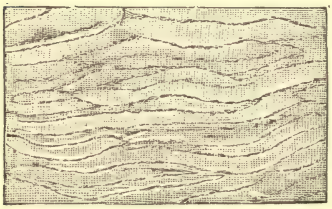


Basalt with the base unindividualized.

The presence of some glass in the ground-mass or base, when this is the only difference, is not of great geological importance. It is, however, the chief characteristic separating rhyolyte (quartz-trachyte) from quartz-felsyte, trachyte from quartzless felsyte, basalt from diabase, andesyte from dioryte, etc.

e. Fluidal or not.—Eruptive rocks in thin slices under the microscope often exhibit wavy lines or bands, which

10.



Rhyolyte; Fluidal texture.

11.

Broken Crystal.

are evidence of movement, or flowing, when in the liquid state. One variety of this texture, in a Nevada rhyolyte, is represented in Fig. 10 (from Zirkel); and another in Fig. 5, on page 442. A somewhat similar appearance occurs

at times in fine sedimentary beds, due to flow of the waters during their deposition. Broken crystals, also, are often evidence of movement of some kind in an igneous rock; it may be that from contraction on cooling, as well as that of flow before solidification. Fig. 11 shows an example from a microscopic section of a labradorite rock (the bands are those developed by polarized light in a triclinic feldspar).

Fluidal lines and texture have been produced also in solid crystalline rocks by powerful movement of one mass of rock on another along with, at times, some metamorphic change, and they may be evidence of such movement.

f. Spherophyric or not.—In consolidation from fusion, especially when the fused material is in the state of glass, there is often a tendency to segregation around centres, and thus to the production of *spherulites* or globular concretions. Spherulites have generally a radiated structure; but other concretions consist often of concentric layers. Obsidian and pearlstone are very often "spherulitic," and sometimes full of large as well as small concentric concretions, either kind consisting of orthoclase with some quartz; and concretions of different constitution occur in other kinds of igneous rocks, and sometimes also in metamorphic rocks. The character distinguishes only varieties. The term *spherophyric* (similar to those describing a porphyritic structure, p. 441) is applied beyond to the variety under any *crystalline* rock which has a spherulitic or concretionary structure. The structure is different from concretionary by *deposition around centres,* such as is exemplified in oölitic and pisolitic limestone and in clay-stones. *Amygdules* differ from either in that they are made by deposition in small vapor-made cavities similar to those of a cellular lava.

4. *Based on Supposed Distinctions in Age.*

Small differences in the texture of igneous rocks have been regarded as sufficient for an offhand distinction of a kind of rock into an *earlier* and a *later* section, and for the introduction of separate names for the two. Such names as *earlier diabase* and *later diabase, earlier dioryte* and *later dioryte, earlier felsyte* and *later felsyte,* the *earlier* including (or thought to) the part older than the Tertiary era of geology, have been used; and also the name *diabase* has been restricted to the earlier, and *doleryte* or *basalt* used

for the later, masses of a single kind of rock. Since all grades of texture, from granite-like (granitoid) to scoriaceous and glassy, may occur in the same mass of igneous rock, whether of Tertiary age or older, the distinction has not the value formerly supposed.

The same principle holds true as regards most metamorphic rocks. The common minerals of these rocks—the feldspars, micas, and chlorites—belong to no particular age.

The only common minerals of metamorphic rocks that are now supposed to be confined to the Archæan—eruptive rocks excluded—are the *accessory* species, chondrodite, phlogopite, zircon, nephelite, the scapolites; and other common species that are much more abundant in Archæan metamorphic rocks than in later are apatite, augite, hornblende, chrysolite, graphite, titanite, corundum, menaccanite, hematite, magnetite; while those less abundant in Archæan than in later metamorphic rocks are micas, chlorites, and the accessory minerals, garnet, staurolite, fibrolite, cyanite, andalusite, and tourmaline.

As to *rocks:* hornblendic and augitic gneisses and granites, syenyte, quartz-syenyte, zircon-syenyte, coarsely crystalline dioryte, and other granitoid hornblendic or augitic rocks, with epidote and nephelite rocks, prevail most among the metamorphic rocks of Archæan time.

5. *The Distinction of Eruptive and Metamorphic.*

Many crystalline rocks occur of both eruptive and metamorphic origin. Some examples of this among the *massive* rocks are granite, syenyte, felsyte, dioryte, gabbro, doleryte or diabase. There are also others among *schistose* rocks; for a schistose structure is now known to be a possible result of pressure during, or subsequent to, the cooling of an eruptive rock, as well as during the formation of a metamorphic rock. Further: in the alteration of an augitic rock to a hornblendic, a hornblende *schist* is sometimes produced. Massive structure is hence no certain evidence of eruptive origin; and neither is schistose of metamorphic, although generally indicating it. Hence any attempt to divide off crystalline rocks into *eruptive* and *metamorphic* is necessarily unsatisfactory. Among rocks, only the following are believed by most petrologists to be *invariably* metamorphic: quartzyte, mica schist, hydromica schist,

chlorite schist, talcose schist, argillyte or phyllyte, serpentine; and until recently serpentine and even quartzyte had been placed among eruptives.

III. INVESTIGATION OF ROCKS.

The constituents of a rock are usually in a granular state, and the ordinary methods of determining their mineral nature are often insufficient. When so coarse that they can be studied with an ordinary pocket-lens, the texture and the methods of study are said to be *macroscopic* (the prefix *macro* being from the Greek *makros*, large); and when too finely granular for this method of study, the term *microscopic* is used.

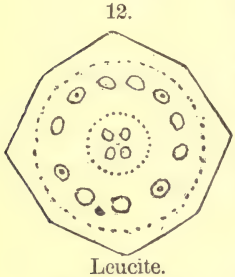
The macroscopic study of rocks is essentially that of ordinary mineralogy, while the microscopic requires that transparent sections of the rock should be made for microscopic examination with ordinary and polarized light, and by other means.

1. *Thin Sections.*—To make the sections: first take a thin chip from the rock, $\frac{1}{2}$ to $\frac{3}{4}$ inch across, and grind it to a smooth surface on a revolving iron plate, fed with fine emery (No. 70) and water. Next secure the chip by the flat surface to a piece of glass by means of a little Canada balsam, and grind the *opposite* side in a similar way, and continue the grinding until the section is quite thin; after which use finer emery and greater care, in order to reach the requisite thinness and transparency without breaking or wholly wasting the specimen. The Canada balsam used is first heated on the glass until the volatile part is driven off, but not until it is made brittle if cooled; and air-bubbles are carefully excluded in attaching the piece of rock to it. The section thus made is then mounted by transferring it to the middle of a glass slide (for which a convenient size is 50 mm. long and 28 mm. wide), made ready with balsam; and, with this end in view, the glass used in the grinding is first heated to soften the balsam, and then the section is pushed from it with a knife-blade on to the prepared slide. Before the transfer, a thin cover of glass is put over the section with a little balsam; the transfer is thus facilitated. Air-bubbles are scrupulously guarded against; and if found in the prepared slide, the mounting has to be repeated.

2. *Distinctive Non-optical Characters Investigated.*— The slicing makes thin sections of all the crystals and grains present. Consequently, the forms of such sections of crystals are studied. Equilateral forms are looked for in isometric crystals; square and rhombic forms in octahedrons; square and 6-sided in cubes; 6-sided and 4-sided, and others, in dodecahedrons (of garnet, etc.); 6- and 8-sided in trapezohedrons; square and rectangular and 8-sided in tetragonal crystals; rectangular, rhombic, and 6-sided in orthorhombic and monoclinic; and rhombic and scalene forms in the case of triclinic species. But it is to be noted that, besides these, other forms will occur under each of the systems of crystallization, arising from oblique sections in different directions, and from the frequent distorted forms of crystals. Further, when the section is one at right angles to the vertical axis it has the interfacial angle of the prism.

Again, *cleavage* lines are often distinct, and among them some will be pretty sure to have between them the cleavage angle of the species: for example, the 124° and 56° of hornblende, or 87° 5′ and 92° 55′ of pyroxene, etc.; and they may indicate the direction of the vertical axis in a prismatic crystalline form. The grains may indicate the species also by the character of the intersecting cracks, and other features.

12.



Leucite.

The microscopic objects inside of crystals are of special interest. These *inclosures* may be habitual in a mineral; they may be arranged symmetrically or concentrically, as in leucite (Fig. 12), or in parallel planes, so as to indicate the crystalline form, if not the species.

The inclosure may be a globule of air alone, and remain fixed as the slide is changed in position; or a liquid may partly fill it, and the air-bubble move as the position of the slide is changed. The liquid may be water, or a kind of mineral oil, or carbonic acid (Fig. 13), liquids that differ in boiling-points, and so admit of identification if the microscope has attachments for the purpose. If it is carbonic acid (CO_2), the air-bubble will disappear at a temperature of 86°–95° F. Liquid CO_2 requires a pressure of 38½ atmospheres at 32° F. to keep it liquid, and it there-

fore occurs encased only in hard and firm minerals, like quartz and topaz. The liquid may contain crystals, as, for example, a cube of salt (Fig. 14) (showing that it is probably salt water), or other kinds of crystals. Some of the *microlites* of an igneous rock are figured on page 442.

Other investigations are made on the section, while it is

13.

Liquid Carbonic acid; *c*, air-bubble.

14.

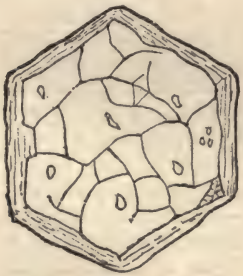
Cube of Salt in a solution of the same.

15.

Magnetite in grouped crystals.

upon the stage of the microscope, by means of acids (see p. 92, and beyond), to test the presence of lime, soda, sulphur, iron, phosphorus, titanium, fluorine, carbonic acid in carbonates, as to the gelatinizing or not of the silica present. A series of reactions made with hydrofluoric acid has been worked out by Boricky, and may be found

16.



Garnet crystal with a border of chlorite.

17.

Chrysolite altered in part to serpentine.

described in works on Petrography. The fusibility may in some cases be tried, and other effects of heat, when provided with proper attachments for the purpose.

The tendency to oxidation or other alteration in some minerals has often produced a clouded or discolored margin in certain kinds of grains, that serve as a distinguishing character; iron-bearing minerals, as hornblende, augite, garnet, magnetite, etc., often having a rusty margin from iron-oxidation, or a green chlorite-like margin from change to a chlorite (Fig. 16); and chrysolite grains or crystals have often, along irregular intersecting fracture-lines, serpentinous and rusty material and magnetite (Fig. 17).

Incipient alteration produces also at times, especially in pyroxene and hypersthene, a peculiar lustre arising from minute points of materials developed within, and the process has been named (by J. W. Judd), from the name schiller spar (or its German origin), *schillerization;* and, accompanying this, there is a tendency in pyroxene to become laminated, or to pass to a diallage.

3. *Optical Characters Investigated.*—The methods of optical investigation are briefly described on pages 70–80. With thin sections, observations are made to ascertain the existence of pleochroism or not in colored minerals, and its characters when existing; whether, with crossed nicols, there is a change from dark to light, or not, as the section on the stage is revolved; for if not, the substance is amorphous, like glass, or isometric, or, it may be, an air-vesicle; whether the optical characteristics are those of uniaxial or biaxial crystallization, or of circular polarization as in quartz; what the position of the plane of the optic axes; whether extinction is parallel or inclined; and what the angle of extinction if inclined; whether there is a twinned or compound structure, a simple twinning or polysynthetic; and so on. The twinning and cleavage lines often aid in determining the direction of the vertical axis, and thus in *orientating* the object (giving it its normal position).

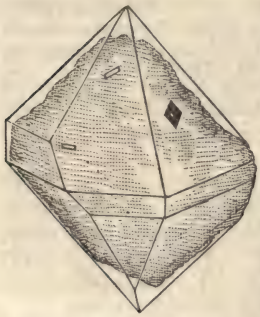
4. *Other points investigated.*—Besides the study of mineral distinctions, there is the microscopic study of mineral changes and the kinds and origin of transformation in rocks.

The changes studied include also (1) methods of consolidation; (2) crystallization; (3) paramorphic transformations; (4) chemical transformations; (5) mechanical movements.

a. In consolidation.—The consolidation sometimes develops crystalline forms. In the case of a siliceous sandstone there are ordinarily additions to the exterior of the

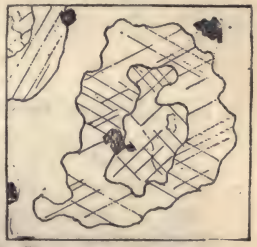
original grains, turning them into crystals of quartz. Grains of a quartz sandstone are always parts of quartz crystals having crystallographic axes; and the material added in the consolidation is added in subordination to these axes, as shown first by Törnebohm and Sorby. It is illustrated in Fig. 18, an enlarged view of one of the grains of the Potsdam sandstone of New Lisbon, Wisconsin (A. A. Young). In this way sandbeds have become an aggregation of minute crystals, although generally failing of this because of the filling of the interstices. The same happens with grains of feldspar and hornblende (Irving, Van Hise).

18.



b. In paramorphic changes.—The paramorphic change of pyroxene to hornblende is well traced out under the microscope. The figure (from Hawes) represents a crystal of augite changed to hornblende except over a central portion, as the cleavage angles in the two parts show. The change is not always a paramorphic change alone, for there is often some loss and gain of ingredients attending the change, the pyroxene often losing in lime and gaining in magnesia. This kind of change has great geological importance, since it is now known that many hornblende rocks, supposed to be eruptive, have been thus made; and that many hornblendic Archæan rocks have had the same kind of origin. Hypersthene undergoes a similar transformation.

19.



Pyroxene changed to Hornblende (Uralite).

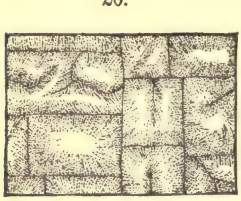
The change of pyroxene to hornblende, first noticed by Rose in 1831, was regarded, until recent years, as only a local occurrence. But ten years since, in November of 1876, Mr. S. Allport described the "dolerytes" of Land's End as more or less altered to hornblende rocks, reporting that some portions had become "half-formed hornblende-schist;" and his paper gives examples of the same from half a dozen other English localities. The change was recognized also by

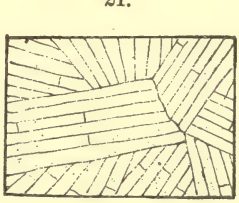
Streng and Wichmann in 1876, and afterward by Pumpelly, Irving, and Wadsworth, among the "greenstones" and other eruptive rocks of Michigan and Wisconsin. In 1878, G. W. Hawes pointed out, in his report on the rocks of N. Hampshire (Geol. N. H., iii 205), the derivation, through the same kind of change, of a hornblende-syenyte from "augite-syenyte" of three N. Hampshire localities, one on Little Ascutney Mountain. In 1883, Irving and Van Hise announced that the hornblende gneisses, granites, and syenytes of the Wisconsin Archæan had been derived from augitic gneisses, granites, and syenytes; and G. H. Williams further illustrated this subject in 1884. In 1886 Van Hise showed that mica had been made from feldspar.

The change in the aragonite of a limestone to calcite takes place at the time of crystallization, and this may be either before or during the time of metamorphism; and that to dolomite takes place probably at the time of *original* consolidation of the calcareous sands, the half-evaporated waters of a sea-border marsh affording the magnesia.

Another example of a paramorphic change is that of the mineral andalusite (G. = 3·1) to cyanite (G. = 3·56). The tendency to the change is strong, andalusite crystals often being altered within. In its incipient stage the interior has often the structure represented much magnified in Fig.

20. 21.





20, and in the later, that in Fig. 21 (both from Hawes), in which the andalusite prism is made up of small prismatic forms of cyanite.

c. In chemical changes.—Some of the *chemical changes* that are microscopically studied are those of chrysolite and other minerals to serpentine (p. 330); of augite to hypersthene or enstatite; of augite (with some aid from feldspar) to chlorite or to epidote; of hornblende similarly to chlorite or epidote or biotite; of garnet to chlorite; of orthoclase to mica; of menaccanite to leucoxene; of magnetite to limonite; and of the beclouding of the feldspars and their change to saussurite, or to chlorite, etc.

In these chemical changes some ingredients are usually set free; and these are often left in part within the space of the original mineral, arranged concentrically along its lines of cleavage, or in its rifts, or scattered about outside. The iron discharged takes the form of magnetite, or hematite, menaccanite, picotite, or chromite, or sometimes native iron.

Fig. 22 (from Hawes) shows the magnetite as it occurs

22.

Altered Hornblende.

23.

Partially altered Chrysolite.

often in altered hornblende, and also biotite (centre of figure) and calcite (lath-shaped grains), which are likewise products of the alteration. The magnetite is a common product in the change of chrysolite to serpentine (Fig. 23, from Judd), representing (enlarged 100 diameters) partially altered chrysolite with the products of decomposition along the rifts. Lime is often discharged in augitic and hornblendic alterations, and if CO_2 is present, calcite is formed, as in Fig. 22. Silica is also often set free; and liquid globules of the CO_2, if present, often become enclosed in the crystallizing quartz. Menaccanite (titanic iron) changes to a grayish white or whitish material called *leucoxene* (see p. 312), which has often a reticulated appearance (Fig. 24, from Hawes) owing to the progress of the change along cleavage lines or rifts.

24.

Leucoxene from Menaccanite.

Such changes are very different from the oxidations due to surface weathering, which are another subject of study.

For a large part of the chemical changes carried on *throughout the mass of the rock*, (1) the presence of moisture was required, many of the minerals formed, as serpentine, chlorite, zeolites, etc., being hydrous; (2) also the presence of carbonic acid, calcite being a very common product; (3) also, for some of the changes, other vaporizable ingredients, including metallic compounds or vapors. The introduction of the vapors into the rock and their general diffusion could have taken place only when the rock was melted, and therefore only while it was rising from the depths below. The liquid rock, at a temperature between 1500 and 2500 F., should it pass, in the ascent, rocks containing some moisture (0·6 p. c. would be a pint to a cubic foot, capable of yielding nearly 30 cubic feet of vapor at the ordinary pressure), or encounter subterranean streams (whose waters might be saline or mineral), vapors in great volume would be sure to form and be forced to enter the *upward-moving* rock (without upward movement in the liquid rock they could not enter or take the form of vapor); or, if passing a limestone stratum, CO_2 would escape and be carried up; and so for other vaporizable materials. The hot vapors would be active agents among the constituent minerals, and, as the right temperature was reached, would begin destructive and reconstructive work, and carry it on with such new results as the declining temperature favored. And thus has probably come many of the changes that have gone on throughout the interior of rocks, producing from the original minerals the chlorite, so common, the serpentine, saussurite, the quartz in crystallized and chalcedonic forms, zeolites, and also copper ores, silver ores, etc. The aluminium-sodium carbonate, called dawsonite, was one of the products in a dike of felsyte intersecting limestone near Montreal.

In the changes where vapors are concerned, the first effect is usually an incipient beclouding of the feldspars and of the other silicates; but when carried forward by heat without or with but a feeble supply of moisture, as appears to have been the fact in many examples of the paramorphic kind, the feldspars may remain unaltered.

Some volcanic glass, when highly heated, loses much volatile matter (moisture?), and is converted into pumice; a dacite-glass lost 8·9 per cent. (J. W. Judd.)

IV. MICROSCOPIC CHARACTERS OF COMMON ROCK CONSTITUENTS.

1. *Isometric or Amorphous.*

Glass.—Optical characters of an amorphous substance (p. 70).

Opal.—Outlines not angular; no cleavage-lines. Often concentric in structure. Sometimes interference colors, due to internal strains. In diatoms and sponge-spicules, no colors.

Leucite.—Outlines 8-sided. Uncolored. Often containing concentric or radiating series of microlites (Fig. 1, page 448) or glass. Often feeble double refraction with polysynthetic twinning bands, crossing at 90° or 45°.

Garnet.—Outlines 6-, 8-, and 4-sided, or irregular. Pale red disk to brown and nearly colorless; irregularly fractured. Sometimes changed at the margin or throughout to chlorite (Fig. 16, p. 449); often contains grains of quartz or other inclusions.

Magnetite.—Squares, rhombs, or hexagonal outlines, often in dendritic groups. Opaque.

Pyrite.—Outlines, squares, and other isometric figures. Opaque. Brass-yellow by reflected light.

2. *Tetragonal and Hexagonal.*

Quartz.—Outlines sometimes sections of quartz crystals, but usually irregular. No cleavage lines. Field never wholly dark on the rotation of a nicol. In oblique or vertical sections interference colors brilliant; in basal sections, if they are not too thin, the characters of circular polarization. By reflected light the quartz grains in a section of whitish granite appear darker than the feldspar grains. Often contain globules of CO_2.

Tridymite.—Hexagonal tables (p. 262 and 443). Interference colors not brilliant. Polarization not circular, but crystals usually too thin to use this distinction.

Nephelite.—Often hexagons and rectangles. Colorless. Gelatinizes; reactions for soda (p. 92). Inclosures common, and often hexagonally arranged.

Tourmaline.—3-, 6-, and 9-sided outlines. No vertical cleavage lines; never finely fibrous. Strongly dichroic.

Scapolite.—Squares, rectangles, 8-sided sections. Few vertical cleavage lines, some transverse. Interference colors brilliant; no dichroism.

Zircon.—Squares, etc.; always in crystals; no cleavage lines. Not distinctly dichroic. Interf. colors brilliant.

Apatite.—Hexagons, long rectangles, needles; cleavage not much distinct. Often having dust-like enclosures. Reactions for lime and phosphorus.

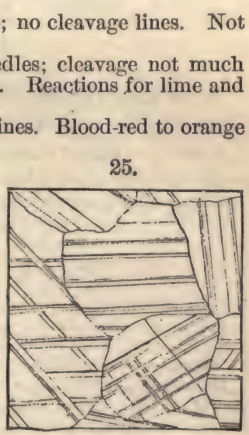
Hematite.—Hexagonal and irregular outlines. Blood-red to orange in very thin slices.

Menaccanite (Ilmenite).—Similar to hematite, but black and opaque instead of blood-red in thin slices. Often a grayish white border and intersecting lines owing to the production of leucoxene by alteration (p. 453). Reaction for titanium.

Calcite, Dolomite.—Grains generally polysynthetically twinned (Fig. 25), the bands parallel to the longer diagonal. Interference colors feeble.

Spherulites also give in polarized light the black cross of a uniaxial substance, owing to the radiated structure; the cross revolves with the revolution of the plate.

25.



Crystalline Calcite.

3. *Orthorhombic.*

Enstatite.—Prismatic, often fibrous. Extinction parallel to vert. axis, or cleavage-lines. Interference colors very brilliant. Not dichroic.

Hypersthene (Amblystegite included).—Like enstatite, but dichroic, yet feebly so unless containing much iron. Usually cleavage parallel to the brachypinacoid. Inclusions parallel to this plane often give a metalloidal lustre. More decomposable than pyroxene, being often altered when the pyroxene (as seen in a thin slice) is fresh.

Chrysolite (Olivine).—Not prismatic in habit, nor fibrous. No regular cleavage lines, but irregular rifts, along which usually altered to greenish, grayish, and brownish, or rusty; or changed wholly to serpentine (p.), and then often containing grains of magnetite, chromite, or picotite. Not dichroic. Interf. colors brilliant.

Staurolite.—Rhombic or 6-sided outlines, and crossed forms through twinning; in transverse section rhombic angle 128°. Cleavage lines not very distinct. Interf. colors brilliant. In small clear crystals strongly dichroic. Very numerous enclosures, especially grains of quartz.

Fibrolite (Sillimanite).—Long prismatic to fibrous; longitudinal cleavage-lines. Extinction parallel to prismatic lines. Interf. colors brilliant. Not dichroic. No tendency to alteration like that of andalusite.

Andalusite.—Prismatic, not fibrous; basal sections nearly square. Crystals usually altered, imperfectly polarizing, containing minute slender secondary crystals, and sometimes, through alteration, having the characters of cyanite. Chiastolite variety has a regular arrangement of impurities, which are partly carbonaceous, this being indicated by the loss B.B. of the color.

Zoisite.—Six-sided and other sections; not finely fibrous. Cleavage-lines in only one direction, parallel to vertical axis. Interf. colors usually little brilliant. Not dichroic.

4. *Monoclinic.*

Orthoclase.—Never columnar or fibrous; cleavage-lines parallel to clinodiagonal. Twinning never polysynthetic. Optic-axial plane in the clinode section. Extinction angle measured with axis *c* (or vertical), 21° 7′. Interf. colors rather brilliant, but less so than in quartz, and if section is very thin, of blue-gray color and faint.

Hornblende.—Sections acute rhombs and hexagons. Prismatic, often fibrous and granular; in transverse sections cleavage lines usually distinct in two directions, the angle 124° 30′, but in vertical sections only vertical lines. Optic-axial plane in the clinode section. Extinction angle (with axis *c*) usually 15°, varying between 2° and 18°. Strongly pleochroic; usually alternating green and yellow through a basal section on rotation of the lower nicol, and bluish through a prismatic section; interference colors not very bright with the black hornblendes.

Pyroxene.—Prismatic and granular; in transverse sections, 4- and 8-sided outlines, with cleavage lines in two directions, the angle 87° 5′. Optic-axial plane in clinode section; extinction angle (with

axis *c*) usually 39° (varying to 54°), the angle on the opposite side of *c* from that in hornblende. Feebly or not dichroic.

Muscovite.—Hexagons and triangles in basal sections, but oblique sections lined in one direction from edges of cleavage-laminæ. Extinction parallel, as in orthorhombic species. Rather feebly dichroic. Optic-axial angle very large, and the plane of the axes macrode. For *biotite*, the same, but optic-angle very small to 0° (p. 291), and strongly dichroic.

Meroxene.—Similar to biotite, but optic-axial plane brachode.

Epidote.—Sometimes columnar, not very fine fibrous. Cleavage lines in one direction, the orthode. Optic-axial plane clinode. Extinction angle (on *c*) 2° 29′. Interf. colors brilliant. Strongly pleochroic.

5. *Triclinic.*

Albite and other Triclinic Feldspars.—Cleavage as in orthoclase; the crystals of fine-grained rocks commonly tabular, parallel to vertical section through axis *a* (clinode section in orthoclase), and hence showing lath-like forms (Fig. 9, p. 444) in thin slices, and usually having the longer side in the direction of the vertical axis (*c*). Generally polysynthetic twinning in such sections lengthwise (not apparent in sections transverse), and showing usually two or more bands of color unless too thin for more than one. Extinction angle, measured on the edge $O/i\text{-}\bar{\imath}$, varying for the species: Albite, 3° 54′–4° 51′; microcline, 15°; oligoclase, 2°–4°; labradorite, 5°–7°; anorthite, 27°–37°.

Cyanite (Kyanite).—Prismatic vertically and flattened parallel to $i\text{-}\bar{\imath}$ (or to section through *c*); cleavage-lines in the prismatic direction. Extinction angle, in sections parallel to $i\text{-}\bar{\imath}$, on cleavage-lines or corresponding edge, 30°, but very thin sections required for the trial.

VI. DESCRIPTIONS OF ROCKS.

The grander subdivisions of rocks here adopted are three in number:

1. Calcareous Rocks or Limestones.
2. Fragmental Rocks, not Calcareous.
3. Crystalline Rocks, Exclusive of the Calcareous.

In the names of rocks, the termination *ite* is here changed to *yte*, as done in the author's "System of Mineralogy" (1868), in order to distinguish them from the names of minerals. Granite is excepted.

I. Calcareous Rocks or Limestones.

1. Uncrystalline.

1. Massive Limestone.—Compact. Colors dull gray, bluish gray, brownish, and black, sometimes yellowish white, cream-colored, nearly white, red of different shades. Tex-

ture varying from earthy to compact semi-crystalline. Hardness about 3, and hence easily scratched with the point of a knife. G. = 2·25–2·75.

In constitution ordinary massive limestone varies between a calcium carbonate or non-magnesian limestone, and a calcium-magnesium carbonate or magnesian limestone. The two kinds are undistinguishable by the eye alone; and they are alike also in losing the carbonic acid when heated B.B. (or in a limekiln), and by the action of acids, as already explained. The *non-magnesian* may consist of calcite, or of calcite with much *aragonite*, since shells and other organic calcareous secretions are often largely aragonite. *Magnesian* limestone—since it has originated from calcareous sediment by a chemical change through magnesian waters (probably sea-marsh brines)—is less likely to contain aragonite; it may be true dolomite in composition (p. 238), but it is generally a mixture of dolomite and calcite.

VARIETIES.—The varieties are alike under the above kinds. They differ in texture, color, presence of fossils or impurities, and in other qualities. Among them are the following: a. *Compact.* b. *Lamellar.* c. *Earthy*, of which *chalk* is a white calcite variety. d. *Oölitic*, consisting of minutely concretionary grains. e. *Pisolitic*, consisting of concretions as large as peas. f. *Bird's-eye*, having scattered crystalline points, as in a limestone of western New York. g. *Conglomerate*, a calcareous pudding stone. h. *Fossiliferous*, consisting chiefly of fossils. i. *Coral* or *Madreporic*, containing or consisting of fossil corals. j. *Encrinal* or *Crinoidal*, containing disks of crinoids. k. *Nummulitic*, consisting of disk-shaped fossils called nummulites. l. *Cherty*, containing siliceous nodules or layers.

The above kinds may be of various colors. The gray and black colors are commonly due to carbonaceous material; for they burn white; but the yellow and red usually to the presence of the yellow or red iron-oxide.

A *black* marble, much used in Eastern U. S., comes from Shoreham, Vermont, and other places near L. Champlain, and near Plattsburg and Glenn's Falls, N. Y.; also from Isle La Motte. A *pudding-stone* marble, of various dull shades of color, from the banks of the Potomac, in Maryland, 50 or 60 miles above Washington, is the material of columns in the interior of the Capitol at Washington.

The *Portor* is a Genoese marble highly esteemed; it is deep black, with veinings of yellow; the most beautiful is from Porto-Venese. The *Nero-antico* is an ancient deep black marble; the *Paragone*, a modern one, of fine black color, from Bergamo; and *Panno di morte*, another black marble with a few white fossil shells.

A beautiful marble from Sienna, *Brocatello di Siena*, has a yellow color, with large irregular spots and veins of bluish red or purplish.

The *Mandelato* is light red, with yellowish white spots. The Madreporic marble is the *Pietra stellaria* of the Italians.

Some of the pyramids of Egypt, including the largest, the pyramid of Cheops, is made of *nummulitic* limestone; and this is the building material of Aleppo, the range of mountains between Aleppo and Antioch being composed largely of this cream-colored rock.

A soft Tertiary limestone occurring in the vicinity of Paris has afforded a vast amount of rock, of an agreeable pale yellowish color, for fine buildings in Paris; and a similar rock has long been used in Marseilles, Montpellier, Bordeaux, Brussels, and other places in Western Europe. The shell-rock, or *Coquina*, of St. Augustine, in Florida, is an aggregate of shell fragments or shell sand.

Fire-marble, or *Lumachelle*, is a dark brown shell marble, having within brilliant fire-like or chatoyant reflections.

Ruin marble is a yellowish marble, with brownish shadings or lines arranged so as to represent castles, towers, or cities in ruins. These markings proceed from infiltrated iron. It is an indurated calcareous marl, and does not occur in large slabs.

Lithographic stone is a compact limestone, very fine and even in texture, and of light gray and yellowish color, affording a very even surface good for use in lithography.

Hydraulic limestone (*Cement stone*, in part) is a gray impure limestone, the quicklime from which makes a mortar that will set under water. It is often a magnesian limestone. The impurity is the source of its hydraulic character, and amounts in the best to 20 to 30 per cent. by weight of the rock; it is clayey or feldspathic material, consisting chiefly of silica and alumina in combination with free silica. The hydraulic limestone (magnesian) of Rondout, N. Y., afforded on analysis—besides lime, magnesia, and carbon dioxide—silica 15·37, alumina 9·13, iron sesquioxide 2·25. In making ordinary mortar, sand (quartz) is mixed with the quicklime and water, and a hydrate of calcium is formed, with much evolution of heat; the hardening requires, further, the drying away of the water; and then CO_2, of the atmosphere, becomes combined after a while with the lime. With "hydraulic cement" the elements of the clayey impurity, distributed in a fine state through the lime, enter into combination with it, and hardening goes on while water is present; and thus it "sets" under water. An artificial hydraulic cement is made in England, by mixing 70 p. c. of chalk with 30 p. c. of the alluvial clay or mud within the lower tidal basins of the Thames and the Medway—the mud supplying the silica and alumina in the proper condition; and this makes the so-called *Portland cement*.

Carbonaceous Oil-bearing Limestones.—A kind used for building in Chicago, of the Niagara period, becomes spotted or streaked with blackish mineral oil, after a few years' exposure to the weather. Much mineral oil and gas are obtained by boring into the Trenton limestone in northwestern Ohio.

Much of the common limestone of the United States is magnesian. That of St. Croix, Wisconsin, the "Lower Magnesian," afforded Owen 42·43 per cent. of magnesium carbonate.

In some limestones the fossils are magnesian, while the rock is com-

mon limestone. Thus, an *Orthoceras*, in the Trenton limestone of Bytown, Canada (which is not magnesian), afforded T. S. Hunt, Calcium carbonate 56·00, magnesium carbonate 37·80, iron carbonate 5·95 = 99·75. The pale yellow veins in the Italian black marble, called "Egyptian marble" and "portor" (see above), are dolomite, according to Hunt; and a limestone at Dudswell, Canada, is similar.

2. Marl.—A clayey or earthy deposit containing a large proportion of calcium carbonate—sometimes 40 to 50 per cent. If the marl consists largely of shells or fragments of shells, it is called *Shell-marl.*

3. Travertine.—A massive limestone (calcium carbonate), formed by deposition from calcareous springs or streams (see p. 236). It is usually cellular, and more or less concretionary. A handsome compact banded kind, translucent, and of great beauty, comes from Tecali, about 35 m. from the city of Mexico.

Stalagmite has a similar origin.

2. Crystalline Limestone.

Granular or **Crystalline Limestone.** (Marble.)—Limestone having a crystalline-granular texture, white to gray color, but sometimes of reddish and other tints from impurities. It is in most cases, if not all, a *metamorphic* rock, and was originally common limestone.

Like common limestone, it may be either—

I. *Calcyte,* calcium carbonate, more or less pure.

II. *Dolomyte,* calcium-magnesium carbonate.

III. *Calcitic Dolomyte,* a mixture of calcite and dolomite, much more common as a rock than pure dolomite. It contains no aragonite, the crystallization undergone changing this mineral to calcite.

The impurities are often *mica, tremolite, white* or *gray pyroxene, scapolite, pyrite;* sometimes *serpentine,* through combination with which it passes into ophiolyte; occasionally *talc, chondrodite, phlogopite, apatite, corundum, chlorite, spinel, graphite,* etc. Talc, tremolite, pyroxene, chlorite, and serpentine are common, especially in the dolomitic kinds.

Varieties.—a. *Statuary marble;* pure white and fine grained. b. *Decorative* and *Architectural marble;* coarse or fine, white, and mottled of various colors, and, when good, free not only from iron in the form of pyrite, but also from iron or manganese in the state of car-

bonate with the calcium, and also from all accessory minerals, even those not liable to alteration, and especially those of greater hardness than the marble which would interfere with the polishing. Calcitic dolomyte often weathers to calcareous sand, owing to a loss of its calcite (the more soluble ingredient) by infiltrating waters.

c. *Verd-antique*, or *Ophiolyte*, containing serpentine. d. *Micaceous.* e. *Tremolitic;* contains bladed crystallizations of tremolite. f. *Canaanite;* contains white pyroxene in a massive form. g. *Graphitic;* contains graphite in disseminated scales. h. *Chloritic;* contains chlorite. i. *Chondroditic;* contains disseminated chondrodite in large or small yellow to brown grains.

White and grayish white marble is abundant in western New England and southeastern New York (Westchester Co.). The texture is less coarsely crystalline in Vermont than in Massachusetts. Fine calcyte marbles are quarried in Dorset, West Rutland, Pittsford, and other places in Vermont, and statuary marble occurs in Pittsford. In Vermont, the best quarries occur where the strata stand at a high angle: the layers were subjected to great pressure in the upturning that gave them this position, and this pressure has soldered many layers together that are separate where the pressure was less; consequently blocks as large as an ordinary house might be obtained at some quarries. Fine marble (dolomyte) is quarried at Lee, Mass. Valuable marble exists also in Pennsylvania, Maryland, and Tennessee. The mottled reddish brown dolomyte from East Tennessee, and mainly from Knox and Hawkins counties, is a beautiful marble; it is a Lower Silurian rock, and although semi-metamorphic, contains Chætetes and other fossils. Another handsome marble is the mottled red of Burlington, Vt., from the semi-crystalline Winooski dolomyte limestone; and a still finer the deeper red (or cherry red), mottled and veined with white, of Swanton, Vt., from the same limestone on the northern borders of the State, both of the Cambrian, and sometimes containing fossils.

The Carrara marble of Italy, the Parian, of the island of Paros (the birthplace of Phidias and Praxiteles), and the Pentelican, from quarries near Athens, Greece, are examples of crystalline *calcyte* limestone. The Carrara marble varies in quality from coarse to true statuary marble, and the best comes from Monte Crestola and Monte Sagro. The *Cipolin* marbles of Italy are white, or nearly so, with shadings or zones of green talc.

Excellent quicklime is made of crystalline limestone, whether it be calcyte or dolomyte. For a good product perfect freedom from imbedded minerals is essential. It does not afford hydraulic lime, as a trial at New Haven, Ct., with an impure feebly crystalline limestone *of right chemical constitution*, proved; the impurity in that case was in the state of mica.

II. Fragmental Rocks, exclusive of Limestones.

1. Conglomerate.—A rock made up of sand and pebbles, or angular fragments of rocks of any kind; ordinarily made by the consolidation of a gravel-bed. (*a*) If the pebbles

are rounded, the conglomerate is a *pudding-stone;* (*b*) if angular, a *breccia.*

VARIETIES.—a. *Siliceous* or *quartzose.* b. *Granitic.* c. *Calcareous.* d. *Pumiceous.* e. *Basaltic.*

2. Grit.—A hard, siliceous conglomerate, called also *millstone grit,* because used sometimes for millstones.

3. Sandstone.—A rock made from sand, or by the consolidation of a sand-bed.

VARIETIES.—a. *Siliceous* or *Quartzose;* consisting chiefly of quartz. b. *Granitic;* made of granitic material or comminuted granite. c. *Micaceous;* containing much mica. d. *Argillaceous;* containing much clay with the sand. e. *Gritty;* hard, and containing small quartz pebbles. f. *Ferruginous;* containing iron-oxide, and therefore having a red or yellowish brown color. g. *Concretionary;* made up of concretions. h. *Laminated;* consisting of thin layers or laminæ, or breaking into thin slabs, a characteristic most prominent in argillaceous sandstones. i. *Friable;* crumbling in the fingers. j. *Fossiliferous;* containing fossils. k. *Feldspathic* (*Arkose*); consisting of quartz and feldspar, the latter in coarsish, cleavable grains; arkose includes also a feldspathic quartzyte.

The paving-stone extensively used in New York and the neighboring States is a *laminated* sandstone, of the upper part of the Hamilton group in geology, quarried just south of Kingston, and at many other places on the west side of the Hudson River. The rock is remarkable for its very even lamination. In western New York and in Ohio, the Devonian sandstones, above the Hamilton group, together with the Waverly group, afford a similar flag-stone. The "brown-stone" used much in New York and elsewhere for buildings is a dark-red sandstone from the Triassic formation, and is from Portland, Conn., on the Connecticut River, opposite Middletown, where it has been quarried since the middle of the 17th century. A lighter-colored "brown-stone" or "*free-stone,*" of the same age, also much used for buildings, comes from Newark, Belleville, Little Falls, and other points in Central New Jersey. The handsome sandstone of light olive-green tint, much employed in architecture, is from the Lower Carboniferous group in New Brunswick. The soft white sandstone, in much esteem among architects because so easily cut and carved, comes from Ohio quarries, in beds of the Carboniferous; it is mostly from a bed about sixty feet thick, called the "Berea grit," and is obtained at Berea and Independence in Cuyahoga County, and Amherst in Lorain County, and elsewhere.

Pyrite is often present in sandstones used for building, and has defaced and is destroying many a beautiful structure by its oxidation, and the consequent decay of the rock.

Sandstones absorb moisture most easily in the direction of the bedding or grain, if there is any distinct bedding; and hence the blocks, when used for a building or wall, should be placed with the bedding horizontal. It is, further, the position in which the stone will stand the greatest pressure.

Grindstones are made from an even-grained, rather friable sandstone, and are of different degrees of fineness, according to the work to be done by them; were it not friable enough to yield in the grinding, the stone would become polished by the worn metal. *Scythestones* are of similar nature, but finer.

Hard siliceous sandstones and conglomerates, occurring in regions of metamorphic rocks, are called "granular quartz," or *quartzyte* (p. 468).

A rock made of sand, especially when not of siliceous material, is often called a *sand-rock*. A *calcareous* sand-rock is made of calcareous sand; it may be pulverized corals or shells, such as forms and constitutes the beaches on shores off which living corals and shells are abundant.

4. Shale.—A soft, fragile, argillaceous rock, having an uneven, slaty structure. Shales are of gray, brown, black, dull greenish, purplish, reddish, and other shades. It may consist of clay and fine sand, or contain much finely pulverized feldspar. It is fine mud consolidated. Often called *slate*, as the slates of the coal-formation.

VARIETIES.—a. *Ordinary*, of different colors. b. *Bituminous shale*, or *Carbonaceous shale* (*Brandschiefer* of the Germans), impregnated with coaly material and yielding mineral oil, or gas, or related bituminous matters when heated. c. *Alum shale;* impregnated with alum or pyrites, usually a crumbling rock; the alum proceeds from the alteration of pyrite or the allied iron sulphides (p. 191–192). Shale graduates into laminated sandstone.

5. Argillyte, *or Phyllyte* (*Roofing slate, Writing slate*).—Argillaceous, slaty, differing from shale in breaking usually into thin and even slates or slabs; sometimes thick-laminated. Often graduates into hydromica and chloritic schists, and also, on the other hand, into shale. Often called *Clay-slate*. Much slate is *hydromica schist;* some is fine *hornblendic* and *epidotic schist*.

VARIETIES.—a. *Bluish black*. b. *Tile-red*. c. *Purplish*. d. *Grayish*. e. *Greenish*. f. *Ferruginous*. g. *Pyritiferous*. h. *Thick-laminated;* affording thick slabs, instead of slates. i. *Staurolitic*. j. *Ottrelitic*. k. *Hornblendic;* microscopally so. l. *Thick-bedded* and often arenaceous (*Graywacke*); a massive rock, affording thick blocks or masses.

Extensive quarries of slate exist in Vermont at Waterford, Thetford, and Guilford, in the eastern slate range of the State; in Northfield in the central range, and in Castleton and elsewhere in the western range. There are excellent quarries also in Maine and Pennsylvania. The rock furnishes also thick slabs for various economical purposes. A trial as to water absorption, and a close examination as to the presence of pyrite, is required before deciding that a slate rock is fit for use, however even its fissile structure.

Kinds with a glossy surface are most likely to be impervious to moisture, but they may be too brittle for good slate.

Catlinite; red clayey pipestone; Minnesota.

6. Tufa.—A sand-rock, conglomerate, or shale, made from comminuted volcanic or other igneous rocks, more or less altered. Colors yellowish brown, gray, brown, sometimes red. Usually loose-textured. Common in volcanic regions. The name, from the Italian *tufo*, is often written in English *tuff*.

VARIETIES.—a. *Trachytic;* made of trachyte, of an ash-gray color, or of other light shades. b. *Andesytic;* made of andesyte. c. *Pumiceous;* made of fragments of pumice. d. *Basaltic;* made from basic igneous rocks, such as doleryte (trap) or basalt; usually yellowish brown or brown in color, sometimes red. *Pozzuolana* is a light-colored tufa, found in Italy, near Rome, and elsewhere; it is used for making hydraulic cement. *Wacke* is earthy, brownish, like an earthy trap or doleryte, usually made of trappean or dolerytic material and compacted into a soft rock.

Much of the "sandstone" and some shales of the Tertiary in the Rocky Mountain region (Montana, Idaho, Colorado, Arizona, etc.) are tufa (mostly andesytic or trachytic); and petrified trees and opal have been formed in it, as explained on p. 259. Tufas, or "ash-beds," occur among the Paleozoic and later beds of Great Britain.

7. Sand. Gravel.—*Sand* is comminuted rock-material; but common sand is usually comminuted quartz, or quartz and feldspar, while *gravel* is the same mixed with pebbles and stones. Sand often contains grains of magnetite, or of garnet, or of other hard minerals existing in the rocks of the region. Occasionally magnetite or garnet is the chief constituent, especially in the upper portions of some sea-beaches.

Volcanic sand, or *Peperino*, is sand of volcanic origin, either the "*cinders*" or "*ashes*" (comminuted lava), thrown upward from the crater of a volcano, or lava rocks otherwise comminuted.

8. Green Sand.—An olive-green sand-rock, friable, or not much compacted, consisting of grains of glauconite, with more or less sand. See p. 329.

9. Clay.—Soft, impalpable, more or less plastic material, chiefly aluminous (kaolinite) in composition, white, gray, yellow, red to brown in color, and sometimes black. Made chiefly from orthoclase feldspar, by decomposition. Often contains much quartz sand, and, if alkali-bearing, pulverized feldspar. See Kaolinite, p. 332.

VARIETIES.—a. *Kaolin*, purest unctuous clay. b. *Potter's clay*, plastic, free from iron; mostly unctuous; usually containing some free silica. *Pipe-clay* is similar. c. *Fire-brick clay*, the same; it may contain much sand without injury, as sand is needed with the clay for brick-making. d. *Ferruginous*, ordinary *brick clay*, containing iron in the state of oxide or carbonate, and consequently burning red, as in making red brick. e. *Containing iron in the state of silicate* (?), and then failing to turn red on being burnt, as the clay of which the Milwaukee brick are made. f. *Alkaline* and *vitrifiable*, containing 2·5 to 5 per cent. of potash, or potash and soda, owing to the presence of undecomposed feldspar, and then not refractory enough for pottery or fire-brick. g. *Marly*, containing some calcium carbonate or ground shells. h. *Weak clay*, containing too much sand for brick-making. i. *Alum-bearing*, containing aluminous sulphates, owing to the decomposition of iron sulphides present, and hence used for making alum.

10. Alluvium. Silt. Till.—*Alluvium* is the earthy deposit made by running streams or lakes, especially during times of flood. It constitutes the flats either side of a stream, and is usually in thin layers, varying in fineness or coarseness, being the result of successive depositions.

Silt is the same material deposited in bays and harbors, where it forms the muddy bottoms and shores.

Læss is a fine earthy deposit, following the courses of valleys or streams, like alluvium, but mostly without division into thin layers. Usually contains some calcareous material in concretions. Occurs in elevated terraces, along the broad parts of large valleys, as the Rhine, Danube, the Hoangho in China, and on some parts of the Mississippi.

Till is the unstratified sand, gravel, and stones, with more or less clay, deposited by glaciers; called also *unstratified drift*.

Detritus (from the Latin for *worn*) is a general term applied to earth, sand, alluvium, silt, gravel, because the material is derived, to a great extent, from the *wear* of rocks through disintegrating agencies, mutual attrition in running water, and other methods.

Soil is a mixture of clay, quartz, sand, and other triturated rock material, along with carbonaceous matters from vegetable and animal decomposition, and from the last gets its dark color and also a chief part of its fertility.

11. Tripolyte (Infusorial Earth).—Resembles clay or chalk in appearance, but is a little harsh between the fingers, and scratches glass when rubbed on it; also occurs firm and slaty from partial consolidation. Consists chiefly

of siliceous shells of Diatoms with often the spicules of sponges, and is silica in the opal state. Forms thick deposits, and is often found in old swamps beneath the peat.

This soft diatomaceous material is sold in the shops under the name of *silex, electro-silicon,* and *polishing powder,* and is obtained for commerce in Maine, Massachusetts, Nevada, California, etc. A bed exceeding fifty feet in thickness occurs near Monterey in California; and other large beds in Nevada near Virginia City, and elsewhere. It is used as a polishing powder; in the manufacture of "soluble glass;" and, formerly, mixed with nitro-glycerine to make dynamite. Occurs *slaty* at Bilin, Prussia; also *hard* or *indurated* in some regions, from consolidation through infiltrating waters, and thus graduates, at times, into chert and opal.

II. Crystalline Rocks, exclusive of Limestones

In the review of the constituent minerals of rocks it has been shown that *orthoclase* and *mica* are closely related in composition, both being eminently potash-bearing species, and that mica has often been derived from feldspar with very little change in the amount of alkali (pp. 287, 438); and also that leucite is closely related to the potash feldspars and nephelite to the soda-lime feldspars. It has also been observed that *hornblende* and *pyroxene* are intimately related, they being alike in chemical constitution; that hornblende is readily derivable from pyroxene by paramorphic change (pp. 272, 451), and that it is chemically unlike biotite and other micas in the usual absence of an alkali, and in other ways. It has further been remarked that rocks are *acidic* or *basic* according to the feldspar in their constitution, without reference to the presence of quartz; and that *quartz* in grains is distributed widely through igneous and metamorphic rocks as it is through sedimentary, and has relatively little value as a ground of distinctions among kinds of rocks (p. 438). It has also been shown that no satisfactory line can be drawn between the kinds of igneous and metamorphic rocks (p. 446).

From these and other considerations explained, we are led to the following arrangement of the crystalline rocks.

A. SILICEOUS ROCKS, OR THOSE CONSISTING MAINLY OF SILICA.

B. FELDSPAR, MICA, LEUCITE, NEPHELITE, SODALITE, OR RELATED ALKALI-BEARING SPECIES, A CHIEF CONSTITUENT.

In the subdivisions 1 to 3 a potash-feldspar is a prominent constituent; in 4 leucite, also a potash-bearing mineral; in 5 and 6 a soda-lime or lime feldspar.

1. **The Potash-Feldspar and Mica Series.** Eminently alkali-bearing rocks, both the mica, whether muscovite, biotite or lepidomelane, and the feldspar, whether orthoclase or microcline, affording on chemical analysis much potash, and the feldspars often also some soda. The soda-feldspar, albite or oligoclase, is a common accessory ingredient. The series shades off into a rock that is chiefly feldspar, and another that is chiefly mica; and in these two extremes the amount of potash yielded is about the same. The mica sometimes contains 4 or 5 per cent. of water, or is a hydrous species (page 335).

2. **Potash-Feldspar and Hornblende or Pyroxene Series.** Related to the granite series, but contains the non-alkaline mineral hornblende in place of mica, with or without quartz. Transitions between the granite and syenyte rocks are common—a bed of true mica schist often becoming hornblendic, or having alternating micaceous and hornblendic laminæ; and so there are similar transitions in other parts of the two series.

3. **Potash-Feldspar and Nephelite Rocks, Hornblendic or not.**

4. **Leucite Rocks.** Augitic or not.

5. **Soda-lime-Feldspar and Mica Series.**

6. **Soda-lime-Feldspar Series, with or without Hornblende or Pyroxene.** The feldspar either of the triclinic species, from albite to anorthite.

C. SAUSSURITE ROCKS.

Saussurite and zoisite are alike, as pointed out by Hunt, in having high specific gravity (3 and over), and thus unlike the feldspar and scapolite series to which they are related in composition.

D. WITHOUT FELDSPAR, OR WITH VERY LITTLE.

1. **Garnet, Epidote, and Tourmaline Rocks.**

2. **Hornblende, Pyroxene, and Chrysolite Rocks.**

E. HYDROUS MAGNESIAN AND ALUMINOUS ROCKS.

A. SILICEOUS ROCKS.

1. Quartzyte, Granular Quartz.—A siliceous sandstone, usually very firm, occurring in regions of metamorphic rocks. Does not differ essentially from the harder siliceous sandstones of other regions. Conglomerate beds are sometimes included. Sometimes friable, passing to loose sand; and flexible (*Itacolumyte*).

VARIETIES.—a. *Massive.* b. *Schistose.* c. *Micaceous.* d. *Hydromicaceous;* it graduating at times into hydromica or mica schist. c. *Feldspathic*, sometimes *porphyritic* (the rock *Arkose*); this variety occurs northeast of Lenox, Mass., near the borders of the towns of Lenox and Washington, and also in Pownal and Bennington, Vt.; when it loses its feldspar it becomes cellular, like buhrstone, and in this state has been used for millstones; by the presence also of mica it becomes *gneissoid* or graduates into gneiss. f. *Friable.* g. *Flexible* (*itacolumyte*); the rock occurs in the gold regions of Brazil and N. Carolina. h. *Andalusitic;* containing andalusite, as in Mt. Kearsarge. i. *Tourmalinic;* containing tourmaline.

In Western New England, in Vermont to the west of the principal ridge of the Green Mountains, and in Berkshire Co., Mass., and Canaan, Ct., in strata of great thickness, also between Bernardston, Mass., and Vernon, Vt.; in the central part of New Hampshire; in the Archæan area of Wisconsin, and in the Rocky Mountain region. It occurs friable, and as sand (used for glass-making), in Cheshire, Savoy, and Washington, in Berkshire Co., Mass.

j. *Novaculitic-quartzyte*, or *Novaculyte* (*Whetstone*). Novaculyte, in part, is an extremely fine-grained siliceous rock. Of this nature is the variety from Whetstone or Hot Spring Ridge, in Arkansas. This ridge, 250 feet in height above the Hot Spring Valley, is made up of the beautiful rock, "equal," says D. D. Owen, "in whiteness, closeness of texture, and subdued waxy lustre, to the most compact forms and whitest varieties of Carrara marble. Yet it belongs to the age of the millstone grit." Dr. Owen supposed it to have received its impalpable fineness through the action of the hot waters on sandstone. An analysis of the rock afforded him (Second Rep. Geol. Arkansas, 1860, p. 24), Silica 98·0, alumina 0·8, potash 0·6, soda 0·5, moisture, with traces of lime, magnesia, and fluorine 0·1 = 100. He states that along the southern flank of the ridge there are over forty hot springs, having a temperature of 100° F. to 148° F. Solid masses from the fine rock have been got out weighing about 1,200 lbs.

2. Siliceous Slate. (*Phthanite.*)—Schistose, flinty, not distinctly granular in texture. Sometimes micaceous, and thus graduates into mica or hydromica schist.

3. Chert.—An impure flint or hornstone occurring in beds or nodules in some stratified rocks. Often resembles felsyte, but is infusible. Colors various. Sometimes oölitic. Kinds containing iron oxide graduate into jasper and clay-ironstone; and others, occurring as layers or nodules in limestone, are whitish, owing to the limestone material they contain. Chert sometimes contains cavities which are lined with chalcedony or agate, or with quartz crystals, making what are called *geodes*.

4. Jasper rock.—Dull red, yellow, brown, or greenish color, or of some other dark shade, breaking with a smooth surface like flint. Consists of quartz, with more or less iron oxide as coloring matter; the red contains the oxide in an anhydrous state, the yellow in a hydrous; on heating the latter it turns red.

5. Buhrstone.—Cellular siliceous, flint-like in texture. Found mostly in connection with Tertiary rocks, and formed apparently from the action of siliceous solutions on preëxisting fossiliferous beds, the solutions removing the fossils and leaving cavities.

Buhrstone is the material preferred for millstones. The buhrstone of the vicinity of Paris, France, has long been largely exported for this purpose. Buhrstone is reported from the Tertiary in Greenville District, South Carolina, 100 miles up the Savannah River.

6. Fioryte. (*Siliceous Sinter, Pearl Sinter, Geyserite.*)—Opal-silica, in compact, porous, or concretionary forms, often pearly in lustre. Deposited from hot siliceous waters, as about geysers (*Geyserite*), and made in other ways.

Geyserite is abundant in Yellowstone Park, and about the Iceland and New Zealand geysers. See Opal, p. 261.

B. CONTAIN AS A CHIEF CONSTITUENT EITHER A FELDSPAR, MICA, LEUCITE, NEPHELITE, SODALITE, OR A RELATED ALKALI-BEARING SPECIES.

I. POTASH-FELDSPAR AND MICA SERIES.

Besides rocks consisting of orthoclase (or microcline), mica, and quartz, others are here included containing but two of these ingredients; and also those consisting chiefly

of orthoclase or of mica, as part of mica schist and much hydromica schist. Mica in many such rocks has been made from feldspar (p. 452).

1. Granite.—Orthoclase (or microcline), mica, and quartz; massive, with no appearance of layers in the arrangement of the mica or other ingredients. G. = 2·5–2·8. The quartz usually grayish white or smoky, glassy (and distinguished by absence of *cleavage*); the feldspar commonly whitish or flesh-colored, its cleavage surfaces usually distinct and brilliant in the sun-light; the mica in bright scales, either whitish (muscovite), or black (biotite, or, at times, some more iron-bearing species). Oligoclase or albite often present, and usually of whiter color than the orthoclase.

Both eruptive and metamorphic. Metamorphic granite often graduates into, or alternates with, gneiss.

VARIETIES.—A. Muscovite granite; B. Muscovite-and-biotite granite, the most common kind; C. Biotite granite (*granityte*); D. Hydromica-granite.

a. *Common* or *Ordinary granite;* color grayish or flesh-colored, according as the feldspar is white or reddish, and dark gray when much black mica is present. Granite varies in texture from *fine* and even, to *coarse;* and that of granite veins has often the mica, feldspar, and quartz—especially the two former—in large crystalline masses. An average granite (mean of 11 analyses of Leinster granite, by Haughton) affords Silica 72·07, alumina 14·81, iron protoxide and sesquioxide 2·52, lime 1·63, magnesia 0·33, potash 5·11, soda 2·79, water 1·09 = 100·35. b. *Porphyritic;* orthophyric, and either (α) small porphyritic, or (β) large porphyritic, and the base (γ) coarse granular, or (δ) fine, and even subaphanitic. c. *Albitic;* contains some albite, which is usually white. d. *Oligoclase granite* (*Miarolyte*); contains much oligoclase. e. *Microcline granite;* contains the potash triclinic feldspar, microcline. f. *Hornblendic;* contains black or greenish black hornblende, along with the other constituents of granite. g. *Black micaceous;* consists largely of mica, with defined crystals of feldspar (porphyritic), and but little quartz. h. *Chloritic.* i. *Zirconitic;* containing zircons. j. *Iolitic;* containing iolite. k. *Spherophyric;* containing concretions consisting chiefly of mica (as at Craftsbury, Vt., where it is called *pudding-granite*). l. *Gneissoid;* a granite in which there are traces of stratification; graduates into gneiss. m. *Microgranite;* having a very fine-grained base in which mica exists with feldspar, the latter often in defined crystals; when quartzophyric, it is one of the kinds of *Quartz-porphyry,* a kind of rock occurring at the junction of granite and an andalusite-hydromica schist on the west side of Mt. Willard, near Crawford's, White Mountain Notch. For muscovite-granites the name *Pegmatyte* was used by Naumann, perverting it from its original use.

The following are prominent regions of granite quarries. In Maine· at Hallowell, a whitish granite, sometimes a little gneissoid; at

Rockport, whitish; at Clarke's Island, spotted gray; at Jonesbury, flesh-red; also in the Mt. Desert region. In New Hampshire, at various places, but most prominently near Concord, a fine-grained whitish granite. In Massachusetts at several points, especially in Gloucester at Rockport, a red granite. (For Quincy "granite" see Syenyte.) In Rhode Island, at Westerly, a fine-grained whitish granite. In Connecticut, at Millstone Point, near Niantic, and at Groton, near New London, a fine-grained whitish granite; at Stony Creek, a pale reddish and cream-colored, but liable to large micaceous spots; at Plymouth, on the Naugatuck, a whitish granite, even and fine-grained, more easily worked than the Westerly. Aberdeen, Scotland, affords the handsome red granite much used for monuments and in architecture; also Peterhead, Scotland.

2. Granulyte. (*Micaless granite, Aplyte, Weiss-stein, Pegmatyte.*)—Consists of orthoclase and quartz, with no mica or very little; often contains some albite or oligoclase and garnets. Coarse to fine-grained. White to flesh-red. G. = 2·6–2·7. Silica 70 to 80 p. c. Sometimes schistose. Metamorphic or eruptive.

VARIETIES.—a. *Common* granulyte; white and usually fine granular; occurs in Saxony, Bohemia, Moravia, usually containing small garnets; also in Western Connecticut and Westchester Co., New York; at Rye, N. H., containing very little quartz. b. *Flesh-colored;* usually coarsely crystalline, granular, and flesh-colored; a coarse flesh-colored "granite" of the Eastern or Front Range of the Rocky Mts., in Colorado; it contains a little albite or oligoclase with the orthoclase. c. *Garnetiferous.* d. *Hornblendic;* containing a little hornblende—a variety that graduates into syenyte. e. *Magnetitic;* containing disseminated grains of magnetite, a kind common in Archæan regions, in the vicinity of the iron-ore beds, occurring in Orange Co., N. Y., and south in New Jersey, and also at Brewster's, Dutchess Co., N. Y., and in Kent and Cornwall, Conn. f. *Graphic;* quartzophyric (*Pegmatyte*), the quartz looking like Persian cuneiform characters over the cleavage surface of coarsely crystallized feldspar. g. *Microgranulyte;* fine-grained, often orthophyric or quartzophyric (making one kind of quartz-porphyry, called also *Micropegmatyte*), found in the Vosges.

Eruptive granulyte has been shown by Lehman to be sometimes schistose as a consequence of pressure. The name *pegmatyte* was applied by Haüy to graphic granulyte from the Greek *pēgma,* joined together, alluding to the quartz in the feldspar.

3. Gneiss.—Like granite in constituents, colors, and specific gravity, but the ingredients arranged more or less in layers, and hence schistose; varying from feebly schistose, or granitoid, to strongly so, the latter easily dividing into slabs. Usually metamorphic.

VARIETIES.—a. *Granitoid;* often graduating into granite. b. *Strongly schistose* and micaceous. c. *Muscovite gneiss;* not common.

d. *Muscovite-biotite* gneiss. e. *Biotite* gneiss. f. *Albitic.* g. *Oligoclastic.* h. *Hornblendic;* containing hornblende as well as biotite. i. *Epidotic.* j. *Garnetiferous.* k. *Andalusitic.* l. *Cyanitic.* m. *Fibrolitic;* containing fibrolite. n. *Quartzose;* containing much quartz. o. *Quartzytic;* consisting largely of quartz in grains and graduating toward quartzyte, as in Berkshire, Mass. p. *Porphyritic;* orthophyric, Fig. 3, p. 440, porph. gneiss of Birmingham, Ct. q. *Spherophyric;* containing concretions of mica or feldspar and mica. r. *Quartzophyric;* containing quartz in defined crystals in a fine-grained base, and sometimes orthophyric also, a kind of *quartz-porphyry* called also *Porphyroid* and *Hyalophyre,* found intercalated among stratified beds in the Ardennes.

4. Greisen.—Massive, without schistose structure. A compact micaceous quartz rock. The mica may be muscovite, lepidolite, or biotite. Occurs in regions of gneiss, granite, or quartzyte, and sometimes graduates into these rocks. Metamorphic. Also called *Hyalomicte.*

Occurs in characteristic form at Zinnwald, in the Erzgebirge, where it sometimes contains tin ore as an accessory ingredient, and is frequently penetrated by veins of tin; also in the tin ore regions of Schlackenwald and Cornwall. Occurs in the region of quartzyte, hornblendic rocks and gneiss, of Upper Silurian or Devonian age, between Bernardston, Mass., and Vernon, Vt., within three miles northeast of the former place; and also near Vernon, but at this place it contains usually a little hornblende, making it a very tough rock, and is intermediate between the quartzyte, hornblendic rock, and mica schist of the region.

5. Protogine. Protogine-gneiss.—Coarse to fine granular, granite-like or gneissoid in structure, and mostly the latter; grayish white to greenish gray; consists of quartz, white or grayish white, rarely flesh-red orthoclase, a dark green mica, and often chlorite, with some greenish white hydrous mica and white oligoclase. Metamorphic.

The dark green mica approaches chlorite, as shown by Delesse, in its very large percentage of iron oxide (Fe_2O_3 21·31, FeO 5·03), but it gave him only 0·90 of water, with 6·05 of potash. Among accessory minerals are hornblende, titanite, garnet, serpentine, magnetite. In an analysis of the protogine as a whole, Delesse obtained Silica 74·25, alumina 11·58, iron oxide 2·41, lime 1·08, water 0·97, leaving 10·01 for potash, soda, and magnesia. From the region of Mont Blanc and other parts of the Swiss Alps.

At Littleton, N. H., a granite occurs consisting of orthoclase, chlorite, and quartz, with a little hornblende; at Lancaster, it is orthophyric; at Lebanon, it is a green spotted rock with some scales of biotite, indicating that this mineral is the source of the chlorite; at Wallin's quarry, N. H., is an epidotic variety.

6. Minette. Ortholyte. (*Mica-syenyte.*)—Gray to brown; fine-grained, compact, massive. Consists of orthoclase with much mica, and a little hornblende, with some apatite and magnetite; sometimes porphyritic. Silica 50 to 65 p. c. Metamorphic?

From the Vosges, near Framont, where it occurs in beds; also in Saxony. The name *Ortholyte* is adopted on the geological map of France. Approaches kersantyte, which is a *plagioclase*-mica rock.

7. Mica Schist.—Mica, with usually much quartz, some feldspar. On account of the mica, usually thin schistose. The schist either *muscovite* schist or *biotite* schist; the latter much the more common; or contains both micas, which is the most common.

Colors silvery to black, according to the mica present; often crumbles easily; and road-sides sometimes spangled with the scales. The disseminated scales or crystals of biotite sometimes set transversely to the bedding. Metamorphic.

VARIETIES.—a. *Ordinary;* coarse or fine, and various in color and constitution according to the kind of mica present or most abundant. b. *Gneissoid;* between mica schist and gneiss, and containing much feldspar, the two rocks shading into one another. c. *Hornblendic.* d. *Garnetiferous.* e. *Staurolitic.* f. *Cyanitic.* g. *Andalusitic.* h. *Fibrolitic;* containing fibrolite. i. *Tourmalinic.* j. *Ottrelitic.* k. *Calcareous;* limestone occurring in it in occasional beds or masses. l. *Graphitic* (or *Plumbaginous*); the graphite being either in scales or impregnating generally the schist. m. *Quartzose;* consisting largely of quartz. n. *Quartzytic;* a quartzyte with much mica, rendering it schistose.

o. *Specular* schist, or *Itabyrite;* containing much hematite or specular iron in bright metallic lamellæ or scales.

8. Hydromica Schist.—Thin schistose, and consisting either chiefly of hydrous mica, or of this mica with more or less quartz; the surface nearly smooth; feeling greasy to the fingers, like talc; pearly to faintly glistening in lustre; whitish, grayish, pale greenish, and also of darker shades. Metamorphic.

This rock used to be called *talcose slate* and *magnesian slate*, but it contains no talc. It includes *Parophite schist*, *Damourite slate* and *Sericite slate* (*Glanz-Schiefer* and *Sericit-Schiefer* of the Germans). Much *argillyte* or roofing slate is here included, as first shown by Sorby.

VARIETIES.—a. *Ordinary;* more or less silvery in lustre. b. *Chloritic;* contains chlorite, and has sometimes spots of olive-green color, as in Orange, east of N. Haven, Ct., and in the Taconic Range on the

western boundary of Massachusetts; graduates into chlorite schist. c. *Garnetiferous.* d. *Pyritiferous;* contains pyrite in disseminated grains or crystals. e. *Magnetitic;* contains disseminated magnetite. f. *Quartzytic;* consists largely of quartzyte, which is thus rendered schistose.

A variety of hydromica schist (but called *argillyte*), from the White Mountain Notch, containing andalusite, afforded Dr. Hawes Silica 46·01, alumina 30·56, iron sesquioxide 1·44, iron protoxide 6·85, manganese protoxide 0·10, magnesia 1·42, soda 1·12, potash 6·66, titanium dioxide 1·93, water 4·13 = 100·22, which is near the composition of a mica. (N. Hampshire Geol. Rep., ii. 233.) Another, from Woodville, N. H., afforded Hawes Silica 60·49, alumina 19·35, Fe_2C_3 0·48, FeO 5·98, lime 1·08, magnesia 2·89, soda 2·55, potash 3·44, water 3·66 = 99·92. This slate, as he recognizes, is chemically like granite; but, by the microscopic study of thin slices, he found it to consist of mica and quartz, with probably some feldspar and chlorite. The close relation in ultimate composition between the extremes of the granite series, granite and some argillyte, is here well illustrated. All the difference that exists may be due simply to difference in grade and conditions of metamorphism.

9. Agalmatolyte. (*Gieseckite,* 1813; *Dysintrybite,* 1852; *Pinite* in part.)—Aphanitic; cut with a knife; composition that of the hydrous mica, damourite. Massive. G. = 2·75–2·85. Greenish gray, reddish gray. Derived mostly from the alteration of nephelite. From Greenland; China; Norway; the Archæan of Lewis Co., N. Y. (See p. 335.)

10. Paragonite Schist.—Consists largely of the hydrous soda mica called paragonite (p. 290); but in other characters much resembling hydromica schist. Metamorphic.

11. Felsyte. (*Euryte, Porphyry, Petrosilex.*)—Compact orthoclase, mostly aphanitic, with commonly more or less quartz intimately mixed; often orthophyric (and called *Porphyry*); sometimes quartzophyric (*Quartz-porphyry*); occasionally spherophyric (*Globular porphyry*); occasionally schistose. Contains sometimes oligoclase, mica, minute apatites, and garnets. Silica 63–81 p. c. Colors white, grayish white, red, brownish red, brown, black. G. = 2·56–2·68. Metamorphic and eruptive.

VARIETIES.—a. *Non-porphyritic,* of various colors. b. *Black.* c. *Orthophyric.* d. *Quartzophyric.* e. *Quartzless;* colors various. f. *Spherophyric;* the *Pyromeride* of Corsica, Schneeberg, and Regenberg, in which the concretions are large, and consist of orthoclase with quartz.

A gray porphyritic felsyte occurs in dikes at Albany and Mt. Pleasant, Groveton and Waterville, N. H.; gray to red about Mt. Pequawbet. A black with "here and there a grain of quartz" at Waterville, N. H., affording only 63·63 p. c. of silica, with nearly the constitution of orthoclase. A nearly quartzless variety at Chambly, Canada (silica

67·60 p. c.). A quartzless felsyte, red, locally at Waterville and Albany, N. H.; also in dikes in Montreal Mtn., containing dawsonite (p. 220). Felsyte from Cottonwood Cañon, W. Humboldt Range, made metamorphic by King, afforded B. E. Brewster Silica 74·74, alumina 14·14, Fe_2O_3 0·79, lime 1·51, magnesia 0·39, soda 0·92, potash 5·29, water 1·88 = 99·66, which is the composition of a normal felsyte. The antique red porphyry ("rosso antico") is a variety of dioryte.

12. Porcelanyte. (*Porcelain Jasper.*)—A baked clay, having the fracture of flint, and a gray to red color; B.B. somewhat fusible and thus differs from jasper. Formed by the baking of clay-beds that contain feldspar. Such clay-beds are sometimes baked to a distance of thirty or forty rods from a trap dike, and over large surfaces by burning coal-beds. Metamorphic.

13. Mica-Trachyte.—Orthoclase and black mica, with a little oligoclase, augite and chrysolite, and glass in the base. Texture fine-grained to compact. Color dark grayish green. Eruptive. Monte Catini, Italy.

14. Trachyte. (*Sanidin-trachyte.*)—Mainly orthoclase, with often disseminated glassy tabular crystals of sanidin, and thence orthophyric with sanidin; oligoclase often present; glass in the base; sometimes spherophyric; often having small needles of hornblende, scales of biotite, magnetite, microscopic apatite. Silica 60 to 64 p. c., but less in kinds containing much oligoclase or hornblende. G. = 2·6–2·65. Owing to the angular forms of the glassy feldspar (sanidin) and the porosity, has a rough surface of fracture, whence the name from the Greek *trachus*, rough. Color ash-gray, greenish, bluish to brownish gray, rarely reddish. G. = 2·6–2·7. Accessory minerals, besides those mentioned, augite, nepheline, haüynite, tridymite. Sometimes augitophyric. Graduates into quartz-trachyte or rhyolyte. Eruptive.

VARIETIES.—a. *Plain trachyte.* b. *Orthophyric*, the sanidin crystals small or large. c. *Oligoclase-bearing* (*Domyte*), and sometimes *oligophyric.* d. *Hornblendic* under each of the above varieties. e. *Sparingly micaceous*, under each. f. *Augitic*, and sometimes *augitophyric*, graduating toward augite-andesyte. g. *Containing pyrope.* h. *Vesicular*, passing into a trachytic lava and pumice.

Common in eruptive regions of Hungary, Italy, and many other parts of Europe. A kind from Ischia afforded Silica 61·49, alumina 20·02; Fe_2O_3 3·11, FeO 2·72, MnO 0·01, magnesia 0·52, lime 1·88, soda 3·39, potash 7·13, phosphoric acid 0·02, ign. 0·46 = 100·75. The trachyte of the Drachenfels, near Bonn, contains oligoclase, and is porphyritic with large crystals of sanidin; contains also some

needles of hornblende, a little augite. Oligoclase-trachyte (*domite*) occurs also in the Puy de Dome, the Euganean Hills (Northern Italy), the Siebengebirge, Eifel. Not common in western N. America, rhyolyte (quartz-trachyte) usually having its place.

15. Rhyolyte or **Quartz-trachyte.** (*Liparyte.*)—Like the preceding trachyte in its rough surface of fracture, color, and more or less glassy, fluidal base, with frequently sanidin crystals; but contains quartz, and is often quartzophyric; occasionally spherophyric. Coarsely crystalline to fine-grained and glassy; also scoriaceous. Often contains some oligoclase, hornblende in needles, black mica; and sometimes tridymite and topaz in cavities. G. = 2·33–2·64. Colors light to dark gray, reddish, yellow, brown, and black. Silica 70 to 82 p. c.; a kind from McKinney's Pass, Nevada, afforded Woodward Silica 74·00, alumina 11·93, Fe_2O_3 2·48, lime 1·56, soda 2·64, potash 5·65, water 1·24 = 99·50; G. = 2·33.

VARIETIES.—Those of trachyte; with also: h. *Coarsely porphyritic*, and almost granitoid (*Nevadite*); i. *Quartzophyric*, one of the various kinds of quartz-porphyry. Graduating toward and into obsidian through *Pearlyte* and *Pitchstone.*

j. *Pearlyte* (Pearlstone, Lithoidal Rhyolyte) has a pearly lustre, often enamel-like; silica 70 to 80 p. c. G. = 2·35–2·50; usually spherophyric, the spherulites consisting of orthoclase with quartz, silica constituting about 85 p. c.

Rhyolyte is more common than trachyte, and occurs in the same and other regions. Common in Hungary, the Siebengebirge; the southern of the Lipari Islands; Iceland. Abundant in Nevada and the rest of the Great Basin between the Sierra Nevada and the Wasatch; the Yellowstone Park. (Hague and Iddings, *Am. J. Sci.*, xxvii., 453, 1884.)

16. Obsidian. (*Volcanic Glass.*)—True glass, but more or less microlitic. Colors gray, dull greenish, purplish to red, brown, and black. By increase of microlites becomes *Pitchstone* (*Retinite*). Sometimes orthophyric, chrysolitic, often spherophyric. G. = 2·3–2·5. Contains 70 to 75 p. c. of silica, and has essentially the constitution of rhyolyte. *Pumice* is a finely scoriaceous variety with linear cells, containing 70 to 78 p. c. of silica.

VARIETIES.—a. *Glass-like* in aspect, and splinters transparent. b. *Semi-lithoidal, pitch-like* in lustre (*Pitchstone*). c. *Spherophyric.* d. *Porphyritic* (*Vitrophyre*). e. *Chrysophyric.* f. *Pumiceous* (*Pumice*).

Obsidian occurs with rhyolyte, in Hungary, the Lipari Islands, in Mexico, etc. In the N. W. part of the Yellowstone Park, N. of Beaver Lake, there is a high bluff of it capped by pumice; also a large area 50 miles east of the bluff; the glass contains large spherulites, and also concentric concretions with irregular cavities between the laminæ,

whose sides are often lined with small crystals of sanidin, tridymite, quartz, and occasionally fayalite (an iron chrysolite); some portions are porphyritic. (Iddings.)

II. POTASH FELDSPAR AND HORNBLENDE OR PYROXENE SERIES.

1. Syenyte. (*Syenite* of Werner.)—Coarse granitoid to microgranitic; sometimes porphyritic. Consists of orthoclase (often with microcline) and hornblende, with no quartz or but little; also often contains biotite and some oligoclase. Silica 58 to 63 p. c. G. = 2·7–2·9. Colors gray to flesh-red and dark gray. Eruptive; also metamorphic?

VARIETIES.—a. *Ordinary.* b. *Orthophyric.* c. *Containing oligoclase.* d. *Biotitic.* e. *Garnetiferous.* f. *Epidotic.* g. *Pyroxenic.* h. *Zirconiferous.* For zircon-syenite, a kind containing elæolite, see p. 478.

From Plauerschen Grunde, Saxony; the Hartz; Norway. A Norwegian afforded Kjerulf Silica 59·93, alumina 16·07, FeO 8·76, lime 4·56, magnesia 2·08, potash 2·82, soda 2·98, water 0·63 = 97·82. Nearly all American syenite is of the quartz-bearing kind. Werner's syenyte being (as says Zirkel for western America) "extremely rare."

2. Quartz-Syenyte. (*Syenyte* of most early geologists. *Hornblende-granite, Syenite-granite.*)—Granitoid to microgranitic; contains quartz, with the ingredients of the above-described syenyte. Silica 70 to 80 p. c. G. = 2·7–2·85. Metamorphic and eruptive.

VARIETIES. Same as above. Rather common in Archæan regions in America, more so than in those of later age. Occurs at Quincy, Mass. (S. of Boston); red and gray, on the coast from Salem, Mass., to beyond Manchester; red at Grenville, Canada, containing little quartz; Barrow I., St. Lawrence; Frankenstein Cliff, White Mts, N. H., etc.

The name *Syenite* is from the Egyptian *Syene* (modern Assouan), the place of the great quarries that afforded the red granite-like rock for obelisks, the lining of pyramids, the columns of temples, sarcophagi, etc., and where there is an unfinished obelisk in its original position. The rock is mostly a red granite, consisting of red feldspar (orthoclase with some oligoclase), quartz, and mica, but having also some hornblende in portions of it. Werner included under the term a hornblende and orthoclase rock free of quartz (that of the Plauerschen Grunde), a kind not occurring in the region of Syene—and this is its restricted use now in Germany. Brongniart and others defined it from the hornblendic variety in Egypt as consisting of feldspar, quartz, and hornblende, making the mica unessential; and this use of the term has been common out of Germany.

3. Syenyte-gneiss.—Like gneiss in schistose structure and in mineral constitution, except that hornblende takes

the place of mica. Some biotite often present. Graduates into amphibolyte.

Common in the Archæan regions of the Adirondacks; Canada; the Highlands of New Jersey and their extension southward and northward, and also in other Archæan regions. It is properly a schistose variety of quartz-syenyte, since structure is not a character of chief importance.

4. Augite-syenyte.—Like syenyte, but containing, with the orthoclase, pyroxene in place of hornblende. Part of the pyroxene often changed to hornblende.

Augite syenyte *free from quartz* occurs at Jackson, N. H. (Hawes), as an eruptive rock, the augite more or less altered to hornblende, and containing also biotite, titanic iron, apatite; at Mountain Pond, in Jackson, N. H.; Little Ascutney Mtn.; in southern Norway, with zircon-syenyte and graduating into it.

Monzonyte, from Monzoni, is mentioned as a variety of augite-syenyte, in which the augite is partly uralitic, and there is much plagioclase (oligoclase to anorthite), with SiO_2 48 to 59 p. cent.; it may be an orthoclase-bearing diabase. Glass in the base. Eruptive.

5. Augite quartz-syenyte. (*"Augite-granite."*)—Similar to the above, except in the presence of quartz.

Occurs in the Archæan region of Wisconsin (Irving, Van Hise), in all stages of gradation from the true augitic rock to a hornblendic, the latter a result of the alteration of the pyroxene to hornblende; also in the Vosges, but containing more plagioclase than orthoclase.

The *gneissic* form of this rock is far more common in Wisconsin than the granitoid; and it occurs also in the Vosges.

6. Unakyte.—Consists of reddish orthoclase and quartz, with yellow-green epidote in place of hornblende. Coarsely crystalline to fine in texture. In Cocke Co., Tenn., on the peaks "The Bluff," "Walnut Mtn.," and "Max's Patch," and also in Madison Co., N. C. (F. H. Bradley, *Am. J. Sci.*, III., vii., 519, 1884).

III. POTASH-FELDSPAR AND NEPHELITE ROCKS, HORNBLENDIC OR NOT.

1. Zircon-syenyte.—Like syenyte, but contains also elæolite, with disseminated zircons; often also ægirine, arfvedsonite, sodalite, eudialyte, eukolite, titanite, leucophane, etc.

From Laurvig, Brevig, Fredericksvärn, etc., Norway; Marblehead peninsula, containing sodalite.

2. Foyayte.—Coarse crystalline-granular; also porphyritic; also aphanitic. Consists of orthoclase, reddish brown nephelite (elæolite) in 6-sided prisms and hornblende or ægyrite, but no zircons; the porphyritic is orthophyric, and has a fine-grained base.

From Mt. Foya and Picota in the Province Algarve, in Portugal; also on the east slope of Blue Mtn., N. J., between Beemersville and Libertyville, where it occupies a dike ¼ m. wide (B. K. Emerson, 1882). Contains ægirite, titanite, sodalite.

3. Miascyte.—Granitoid to schistose. Consists of microcline, elæolite, biotite, with some quartz; often also zircon, pyrochlore, monazite, sodalite, cancrinite, etc. Metamorphic?

Named, by G. Rose, from Miask, Ilmen Mts., where it has a wide distribution. Occurs also on Pic Island, L. Superior; Litchfield, Me., containing cancrinite and sodalite, and lepidomelane in place of biotite.

4. Ditroyte.—A coarse to fine-grained rock, consisting of microcline, nephelite (elæolite), and sodalite.

From Ditro in Eastern Transylvania, where it is associated with syenyte and mica schist, and lies between these two rocks.

5. Phonolyte. (*Clinkstone.*)—Compact; gray, grayish blue, brownish gray; more or less schistose or slaty in structure; tough, and usually clinking under the hammer, like metal, when struck, whence the name. G. = 2·4–2·7. Consists of glassy orthoclase, with nephelite and some hornblende. Sometimes porphyritic. Composition of the Bohemian phonolyte (G. Jenzsch): Sanidin (glassy orthoclase) 53·55, nephelite 31·76, hornblende 9·34, titanite 3·67, pyrite 0·04 = 98·36. Rarely amygdaloidal. Accessory minerals, oligoclase, pyroxene, nosite, haüynite, leucite. Eruptive only.

Occurs in Auvergne; Brisgau; Bohemia. Not reported from N. America.

IV. LEUCITE ROCKS, WITH OR WITHOUT AUGITE.

Usually some sanidin (orthoclase) is present, and often also some nephelite and labradorite.

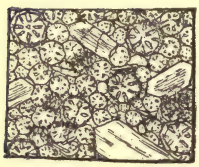
1. Amphigenyte. (*Leucitophyre.*)—Consists of leucite (amphigene), augite, more or less glass, with often some chrysolite, nephelite, sanidin, labradorite, brown mica

(meroxene); accessory minerals, sodalite, haüynite, nosite, melanite, magnetite. Dark gray to grayish black; fine-grained to scoriaceous and pumiceous; often leucitophyric. G. = 2·5–2·9. Silica 47–50 p. c.; but 50 to 58·5 with much feldspar.

VARIETIES.—a. *Fine grained*, with the leucite in grains. b. *Leucitophyric*. c. *Sanidophyric*. d. *Nephelophyric*. e. *Haüynophyric* (*Haüynophyre*). f. *Chrysolitic* (*Leucite basalt*). g. *Scoriaceous*. The name amphigenyte was given 50 years since to the leucite-rock of the Vesuvian region by Cordier, and is as good as any of later origin. Constitutes for the most part the lavas of Somma and Vesuvius; also at Capo di Bove; the Eifel; the Albanian Mts.; the Erzgebirge at Böhmish-Wiesenthal, and elsewhere. Not yet found in America.

2. Leucotephrite.—Like the above and occurring in the same regions, but containing much labradorite.

3. Leucityte.—A grayish to greenish gray rock consisting of leucite crystals, and having a porous leucitic ground-mass, with very little augite and some biotite (the large crystals in the figure annexed); also traces of magnetite and biotite. Silica 54·42 p. c.



From Point of Rocks, Wyoming. An associated porous rock passes into a micaceous pumice. (Figure from Zirkel.)

V. SODA-LIME-FELDSPAR AND MICA ROCKS.

Kersantyte. (*Mica-dioryte, Mica-porphyrite, Soda-granite, Hemidioryte.*)—Granitoid to fine-grained; grayish to brown and grayish black. Chiefly oligoclase and biotite, usually some quartz, hornblende, orthoclase, magnetite, apatite; sometimes oligophyric. Silica 53 to 67 p. c. Graduates, through the increase of hornblende and loss of biotite, into dioryte.

From the Vosges, at Visembach and St. Marie; porphyritic varieties (*Mica-porphyrite*) in Auvergne; Schwarzwald, etc. Granitoid, at Stony Point, on the Hudson, and near Cruger's, in Cortlandt, N. Y.

VI. SODA-LIME FELDSPAR AND HORNBLENDE OR PYROXENE ROCKS.

The kinds of rocks here included differ chiefly in the kind of triclinic feldspar present—the minerals horn-

blende and pyroxene (diallagic or not) having essentially the same composition. One series has oligoclase as the predominant feldspar, and another the more basic feldspars, labradorite, anorthite. Under each there is great diversity in the kinds of rocks as to texture, for coarse-grained or granitoid, fine-grained, aphanitic, and glass-bearing varieties occur in each series, and sometimes (as shown by Hague and Iddings from Nevada investigations, and by Judd and Lotti) in the same eruptive mass. The oligoclase kinds often graduate into labradorite, obscuring distinctions, and sometimes also into orthoclase rocks, as in Wisconsin (Irving). The hornblendic kinds have in many cases resulted from the alteration of the pyroxenic (p. 451). The name *trap* is a common and convenient designation of the dark-colored fine-grained pyroxene kinds.

1. Dioryte. Quartz-Dioryte. (*Greenstone* in part.)—Typical dioryte: chiefly oligoclase and hornblende, with often some orthoclase and biotite; chlorite usually present in dark green varieties, and sometimes epidote. No glass present. Texture granitoid to aphanitic; often porphyritic; sometimes spherophyric. Color often grayish white to greenish white for the coarser kinds; olive-green to blackish green and red for the finer. Very tough. Silica 50–64 p. c., when free from quartz. G. = 2·66–3·0.

The *quartz-bearing* and *quartz-less* kinds constitute two sections having similar varieties. Dark red, brownish red, and dark green porphyritic kinds, compact in base, have been called *Porphyryte*. Metamorphic and eruptive.

VARIETIES.—a. *Granitoid;* granite-like in texture. b. *Fine-grained.* c. *Aphanitic.* d. *Oligophyric* (*Porphyrite, Hornblende-porphyrite*), the base usually fine-grained to aphanitic, a red kind, the antique red porphyry, or "Rosso antico" (Fig. 1, page 440). e. *Schistose* (*Dioryte schist*), usually chloritic. f. *Micaceous,* containing much biotite.

Occurs in Saxony, Thuringia, Bohemia, the Vosges, and other parts of Europe, and often porphyritic; also in Scotland and Ireland; Mt. Dokhan, Egypt (the "rosso-antico); in New York, on the Hudson, north of Cruger's, a granitoid kind having the hornblende prisms in some places 1–4 in. long, and graduating into a granitoid kersantyte; also at Littleton, Lancaster, and Lisbon, N. H.; W. and N. W. of Baltimore, where it has been derived from the alteration of "gabbro" (G. H. Williams). A dioryte from the Hartz afforded Silica 54·65, alumina 15·72, Fe_2O_3 2·00, FeO 6·26, MnO *trace,* magnesia 5·91, lime 7·83, potash 3·79, soda 2·90, water 1·90 = 100·96.

Banatite and *Tonalite* are like quartz-dioryte in most characters.

Each contains some biotite, the latter much of it. Banatite is from the Banat, and Tonalite from near Tonale, in the Southern Alps. *Hemithrene* is a dioryte containing calcite (and effervescing with acids); probably an altered dioryte.

Mica-dioryte.—Dioryte often passes by a gradual disappearance of the hornblende, and the appearance of scales of black mica (biotite), into the non-hornblendic rock kersantite, called also *mica-dioryte.* See p. 480.

2. Augite-Dioryte.—Containing augite with the oligoclase, and but little hornblende; the augite often more or less altered to hornblende. Colors dark gray to greenish black and black, without any glass. Hornblende-dioryte has often resulted from the alteration of augite-dioryte.

Observed under partially altered form by Wichmann, Wadsworth, and Irving in northern Michigan and Wisconsin; occurs also in Cortlandt, N. Y., and on Stony Point, where it is partly altered to hornblende-dioryte (G. H. Williams).

Hypersthene-dioryte, a rather fine-grained rock containing hypersthene in place of augite, but partly altered to hornblende, occurs also at Stony Point and in Cortlandt. Its mineral constitution is that of noryte.

Ophyte.—A greenish black fine-grained to aphanitic rock, often schistose, containing pyroxene in the form of diallage, with hornblende and small crystals of oligoclase, some biotite, chlorite, epidote, sometimes spherophyric. Common at Biarritz and elsewhere in the Pyrenees.

3. Labradioryte. (*Labradorite-dioryte, Greenstone* in part.)—Labradorite or anorthite with hornblende. Texture usually fine-grained, crypto-crystalline to aphanitic, without glass. Color light grayish green to dark olive-green, blackish green or gray, and sometimes black. Very tough. G. = 2·8–3·1. Often contains chlorite and magnetite. Metamorphic and eruptive.

VARIETIES.—a. *Granular crystalline.* b. *Compact,* or fine-grained. c. *Porphyritic;* the feldspar in whitish or greenish white crystals disseminated through a fine-grained base, making a greenish "porphyry." d. *Pyroxenic;* containing some disseminated pyroxene. e. *Magnetitic;* containing magnetite or titanic iron. Occurs in the Urals; in Orange, west of New Haven, Conn., both massive and porphyritic; of black color in dikes at Compton Falls, N. H. (Hawes). The porphyritic variety—a metamorphic rock—afforded Hawes, Silica 48·61, alumina 17·81, iron sesquioxide 0·25, iron protoxide 8·46, manganese protoxide 0·20, lime 11·16, magnesia 7·76, soda 2·77, potash 0·47, water 1·63, titanium dioxide 1·35 = 100·47; G. = 3·01; the crystals of the porphyritic variety, according to an incomplete analysis by E. S. Dana, consist of anorthite; they are mostly altered, and probably in the state of saussurite.

Epidioryte consists of plagioclase with hornblende, some quartz, a

little orthoclase, and some pyroxene. Silica 56 p. c. *Chlorophyre* of Quenast, Belgium, is related.

An *augite-diorryte containing labradorite* in place of oligoclase is identical in mineral composition with gabbro and basalt.

4. Andesyte. (*Hornblende-andesyte.*)—Consists of oligoclase or andesite and hornblende, with often some orthoclase or sanidin, and biotite. Sometimes porphyritic. Color usually dark to light green, and gray, sometimes purplish; aspect more or less trachytic. Some glass in the base, as in lavas. Silica 59–63 p. c. G. = 2·6–2·7. Texture varies from coarsely crystalline to microcrystalline, trachytic, rhyolitic, glassy, scoriaceous, and at Washoe, Nevada, these wide extremes exist in the same eruptive mass, according to Hague and Iddings.

5. Dacyte. (*Quartz-andesyte.*)—Like the above, but containing disseminated quartz grains, and sometimes quartzophyric. Silica 65 to 70 p. c. Often graduates into the orthoclase rock, rhyolyte.

VARIETIES of Andesyte and Dacite.—a. *Fine-grained.* b. *Porphyritic.* c. *Micaceous* (*Hornblende mica-andesyte*). d. *Hypersthenic.* e. *Scoriaceous.* f. For dacyte, *quartzophyric.*

From the Andes in Cotopaxi, Chimborazo, etc. Common, especially the dacyte, over the Great Basin, in Nevada and elsewhere, and in the volcanoes of the Pacific border. *Propylyte,* of Nevada, is altered andesyte, as first pointed out by Wadsworth.

Timacyte is labradorite-andesyte, from Timokthale, Bulgaria.

6. Augite-Andesyte.—Contains the same feldspars as andesyte; but augite is present, and often hypersthene, in place of hornblende, but often is in part changed to hornblende. Amount of silica 56 to 61 p. c., or 62 to 77 from the presence of quartz. More or less glass present. Texture crystalline, granular to aphanitic and fluidal; also glassy, and resembling pearlyte and obsidian, and spherophyric. Eruptive.

VARIETIES.—There are two series: A. *Ordinary,* that is, without chrysolite, or only in traces. B. *Chrysolitic,* chrysolite being in disseminated grains or crystals. Under each there are varieties. a. *Ordinary.* b. *Hornblendic* (*Hornblende-augite-andesyte*). c. *Chloritic,* containing disseminated chlorite and feeble in lustre. d. *Amygdaloidal* (and chloritic). e. *Porphyritic.* The chrysolitic variety is one of the rocks that has been called *Melaphyre.* Reported from the Great Basin, but much of the rock there is hypersthenic, and belongs to the following. *Trachy-doleryte* is essentially augite-andesyte; a felsytic variety occurs among the English Cumberland lavas.

7. Hypersthene-Andesyte.—Like augite-andesyte, and may be considered a variety containing hypersthene in place of most of the augite. Color gray, bluish gray, reddish, black. G. = 2·6–2·7. Often porphyritic. Sometimes chrysolitic. Passes into glassy and pumiceous varieties.

Constitutes part of the rock of Buffalo Peaks, Colorado, and of andesyte localities in the Great Basin; common rock at Mt. Rainier and Mt. Hood, Mt. Shasta, at Washoe, Nevada. When chrysolitic, near basalt in its characters.

8. Hyperyte. (*Hypersthene-gabbro. Noryte* in part.)—Granitoid. Consisting chiefly of labradorite or anorthite, with hypersthene, usually some pyroxene; also biotite and magnetite; sometimes, chrysolitic.

From the Hartz; Hitteroë, Egersund, Norway; St. Paul, coast of Labrador; West and N. West of Baltimore, Md.

9. Gabbro. Granitoid; consisting chiefly of labradorite and pyroxene, often a diallagic variety; often contains some hornblende; also magnetite or ilmenite; sometimes chrysolitic. No glass. Color dull flesh-red to brownish red and dark gray. G. = 2·7–3·1, varying with the proportion of pyroxene, which is sometimes small. The chrysolite is often in part changed to serpentine.

VARIETIES.—a. *Granitoid.* b. *Feldspathic*, the amount of pyroxene small. c. *Chrysolitic* (*Olivine-gabbro*), containing disseminated chrysolite, which is often more or less changed to serpentine. d. *Microcrystalline*, and thus graduating insensibly into doleryte or basalt. Common in the Adirondacks and the Archæan of Canada; Waterville, N. H., where it is chrysolitic, and is associated with an altered variety containing serpentine; also on Mt. Washington River.

The name Gabbro is of Italian origin. It is now, and has long been, used in Italy for a green serpentine rock. Signor Lotti says (1885) that it is not possible there to adopt the perverted use of lithology. *Gabbro rosso* in Italy is a reddish altered gabbro. The name *Euphotide* in Italy covers a labradorite rock like the above in mineral constitution, and also the same in which the labradorite is altered to saussurite, the former graduating into the latter.

10. Doleryte.—Texture varying from a rather fine-grained granitoid to aphanitic; often granulitic through the interior of the eruptive mass, and aphanitic and glass-bearing along the walls where cooled rapidly; also rhyolitic, and scoriaceous. Consists, like gabbro, of labradorite and pyroxene, with the pyroxene sometimes diallagic; often porphyritic; often contains chrysolite (olivine); and magnetite or me-

naccanite in minute grains. Color dark gray to grayish black, greenish black and brownish gray, black; G. = 2·75–3·1. Includes the most of what is called *trap*. Chrysolitic kinds sometimes altered to impure serpentine.

VARIETIES.—A. *Diabase*. Granitoid to fine-grained and aphanitic; the granitoid variety essentially like gabbro. Free from glass. Often chrysolitic. Often chloritic and amygdaloidal (*Spilyte*). Often labradophyric, sometimes anorthophyric. Often augitophyric. Occasionally contains quartz. Graduates imperceptibly into the following:

B. *Basalt*. Granulitic to aphanitic (*Anamesyte*) and scoriaceous. Glass present. Otherwise as above. Lavas, stony and scoriaceous, here included. Quartzophyric, at Lassen's Peak (Diller).

Abundant in most regions of volcanic and other igneous rocks. Constitutes the trap ridges of the Connecticut Valley, Palisades on the Hudson, and similar ridges in Nova Scotia, Pennsylvania, Virginia and N. Carolina, where some are chloritic and amygdaloidal; also covers large areas over the western slope of the Rocky Mountains. An anorthophyric variety at East Hanover, N. H., has anorthite crystals ½ to ¾ in. broad, and same occurs also at Moose Mtn. and in Stark, N. H., and at Concord, Vt.; and with crystals ¼ in. of anorthite, and distantly spaced, in the Buttress dike crossing West Rock, Woodbridge, and Orange, near New Haven, Ct. On the use of the term diabase see p. 445. *Palatinite* is related to the above.

The "antique green porphyry," or *Porfido verde antico*, figured on page 440, in Fig. 2, is a porphyritic doleryte or diabase, the feldspar being labradorite, and the other chief constituent, augite, with also some chlorite or viridite, which last is the source of the greenish color. It is from the South Morea, between Lebetsova and Marathonisi. Delesse obtained, from the compact base, Silica 53·55, alumina 19·34, iron protoxide 7·35, manganese protoxide 0·85, lime 8·02, soda and potash 7·93, water 2·67. In view of its firmness, and its contrast in this respect with most chloritic doleryte, it may be queried whether the rock is not a *metamorphic* doleryte. It closely resembles the porphyritic labradioryte from the vicinity of New Haven, Conn. (which is chloritic and metamorphic), though differing from it in containing pyroxene instead of hornblende. A similar porphyry is reported from Elbingerode in the Hartz, Belfahy in the Vosges, and Barnetjern near Christiania in Norway.

The name *Melaphyre* was first used for a black porphyry described as having feldspar crystals in a compact hornblendic base; since, for dark augite-oligoclase rocks (dioryte or andesyte), porphyritic or not; compact augite-labradorite rocks (diabase or doleryte), non-porphyritic; the same, chrysolitic, and amygdaloidal or not. Like anamesyte and spilyte, it is not needed in petrography.

11. Tachylyte. (*Hyalomelan.*)—Blackish glass, or pitchstone, connected with augitic igneous rocks or lavas; sometimes porphyritic; often contains grains of augite or chrysolite. The former affords on analysis 55 per cent. of silica, and the latter 50 to 55.

Tachylyte is from Säsebühl, Germany; north shore of L. Superior, etc.; *Hyalomelan* from a volcanic rock in the Vogelsgebirge. *Siderомelan* is a tachylyte from Iceland. *Limburgyte* is an augitic glass.

12. Eucryte.—A doleryte-like rock, consisting chiefly of anorthite and augite, with sometimes chrysolite. Occurs granitoid to fine-grained, and as a lava.

From Elfdalen, Norway; Puy de Dome, France; Carlingford, Ireland, etc.

Troctolyte consists of anorthite and chrysolite, with some augite.

13. Corsyte. (*Orbicular Dioryte.*)—Anorthite and hornblende with some quartz and biotite. Spherophyric, and consisting chiefly of concretions of anorthite and hornblende with a little quartz.

From Corsica; the Shetlands; Bohemia; Yamaska Mtn., Canada.

14. Anorthityte.—Coarsely crystalline-granular. Consists largely of anorthite, or a feldspar near it in composition. Light gray to white or faintly greenish; an occasional trace of augite and chrysolite. An analysis of the "anorthite" gave the oxygen ratio 1 : 2·4 : 4·15, with about 47 p. c. of silica, showing divergence from anorthite (Irving).

On the N. shore of L. Superior, between Split Rock River and the Great Palisades, and in Carlton's Peak, near the mouth of Temperance R. Eruptive. (*Anorthite-rock* of Irving.)

15. Nephelinyte. (*Nepheline-doleryte, Tephryte.*)—Nephelite with augite and some magnetite; with or without chrysolite; often nephelophyric. Ash-gray to dark gray. Frequent accessory minerals, leucite, haüynite, sanidin, biotite, hornblende, etc.

VARIETIES.—a. *Ordinary.* b. *Nephelophyric.* c. *Chrysolitic* (*Nepheline-basalt*). d. *Plagioclase-bearing* (*Nepheline-tephryte*). e. *Melilitic* (*Melilite-basalt*). f. *Haüynitic.* g. *Hornblendic* (*Buchonite*).

Occurs at Katzenbuckel, in the Oderwald, Eifel, Schwarzwald, etc.

16. Teschenyte.—Felsytic in texture; dark bluish green. Consists chiefly of anorthite or labradorite, nephelite, hornblende, and augite. The hornblende sometimes in large black prisms. Accessory minerals black mica, apatite.

From Tetschen, Moravia.

C. SAUSSURITE ROCKS.

Euphotide. (*Gabbro* in part.) Grayish white to grayish green, and sometimes olive-green; very tough. G. = 2·9–3·4. Consists of saussurite with diallage or smaragdite; the saussurite often accompanied by labradorite, or other triclinic feldspar; Silica 43 to 52 p. cent. The saussurite probably altered labradorite or other triclinic feldspar, and the smaragdite altered diallage. Graduates into gabbro, a related rock in which the labradorite is unaltered, and also into the finer grained labradorite-rocks of similar constitution, diabase and basalt; in Italy both the euphotide and gabbro are called euphotide. Chrysolite is often present, as in gabbro, and also serpentine as a result of the alteration of chiefly the chrysolite. Altered eruptive (Lotti).

Varieties.—a. *Diallagic;* diallage the chief foliated mineral. b. *Smaragditic;* emerald-green smaragdite, the foliated mineral. c. *Micaceous;* contains mica. d. *Chrysolitic.* e. *Serpentinous.* f. *Garnetiferous.* g. *Schistose;* especially when talc is present. h. *Spherophyric;* contains aphanitic concretionary spheroids of the saussurite mineral, as in the "*Variolite* de la Durance," and of Mt. Genèvre, and associated with ordinary euphotide. The variety obtained at Orezza is the *Verde di Corsica,* of decorative art.

Occurs near Lake Geneva, in Savoy; at Mt. Genèvre in Dauphiny, near the boundary between France and Italy; at Allevard, in the northeastern part of Isère; in the valley of the Saas, north of east of the Monte Rosa region; in the Grisons; near Leghorn and Bologna; near Florence, at Mt. Impruneta; Corsica, in the Orezza valley; Silesia; I. of Unst.

D. ROCKS WITHOUT FELDSPAR.

1. GARNET, EPIDOTE, TOURMALINE ROCKS.

1. Garnetyte. (*Garnet Rock.*) Massive fine-grained garnet. Color yellowish or buff to greenish white. Tough. G. = 3·3 to 3·54. H. = 7·0.

From Vieil Salm, Belgium, a manganesian garnet (Renard), being the superior yellowish novaculite or razorstone, where it makes layers in a hydromica (sericite) schist; St. François and Orford, Canada, an alumina-lime garnet (Hunt).

2. Eclogyte. (*Omphacite.*)—Fine-grained granular rock, consisting of red garnet in a base of grass-green smaragdite, with occasionally zoisite, actinolite, and mica. Very tough.

Also essentially the same rock, of dark color, consisting of reddish or brownish yellow garnet with black or greenish black hornblende and some magnetite.

3. Epidosyte.—Compact, pale green to pistachio-green. Very tough and hard. Consists of epidote and quartz. A variety from the Shickshock Mts., Gaspé, of a pale yellowish color, has H. = 7 and G. = 3·04–3·09 (Hunt).

4. Tourmalyte. (*Schorl Rock.*)—Granular and compact schistose. Consists of tourmaline and quartz, with often chlorite, mica, and sometimes tin-ore. Occurs massive in Cornwall; schistose at Eibenstock, in Saxony; in Marble Mtn. and Ragged Ridge, Warren Co., N. J. (G. H. Cook).

2. HORNBLENDE, PYROXENE, AND CHRYSOLITE ROCKS.

In these rocks chrysolite when present is often changed to serpentine, and sometimes the pyroxene also.

1. Pyroxenyte.—Consists of augite, coarse or fine crystalline-granular. Sometimes chrysolitic. Cortlandt, N. Y., and Stony Point.

2. Picryte.—Blackish green, grayish to brownish red. Crystalline-granular. Consists of chrysolite, with augite or diallage or hypersthene; the augite sometimes in crystals; often partly altered to serpentine; also some magnetite. Graduates into chrysolitic basalt. Changes to hornblende-picryte, and into a serpentine rock. From the Fichtelgebirge. *Eulysyte* contains also garnet; Sweden.

Limburgyte has the same constituents, but is glassy. Silica 43 p. c. From Limburg in the Kaiserstuhl.

3. Lherzolyte.—Greenish gray; crystalline-granular. Consists of chrysolite, enstatite, whitish pyroxene with chrome-spinel (picotite) and sometimes garnet. Partly altered serpentine. From Lake Lherz.

4. Amphibolyte. Hornblendyte.—Coarse to fine crystalline-granular. Either massive or schistose. Some kinds chrysolitic. Occurs as a metamorphic rock as well as eruptive. Sometimes derived from the alteration of an augitic rock. A paler green variety, consisting of actinolite, has been called *actinolyte*.

VARIETIES.—a. *Massive*, coarse crystalline. b. *Fine crystalline.* c. *Aphanitic.* d. *Chrysolitic.* e. *Actinolyte;* consisting of pale green hornblende. f. *Schistose;* Hornblende schist.

Common as a schist and massive rock in metamorphic regions. A coarsely crystalline, chrysolitic eruptive rock at Stony Point, on the Hudson River, and on the opposite side of the river in Cortlandt, N. Y.

5. Hornblende-Picryte.—Dark greenish to greenish black and gray; coarse to fine grained. Consists of hornblende, chrysolite, and serpentine, with magnetite; the hornblende mostly or wholly altered augite and the serpentine altered chrysolite; usually more or less augite. From Anglesey and Carnarvonshire.

6. Dunyte. Peridotyte.—Pale green, grayish green, granular; consisting almost wholly of chrysolite; often partly changed to serpentine. G. = 3–3·1.

From Mt. Dun in New Zealand, where it is eruptive. Also from Macon Co., N. Carolina. A related rock is supposed to be the origin of the serpentine rocks of Baste in the Hartz, etc.

7. Glaucophanyte.—Consists chiefly of the blue soda-bearing hornblende, glaucophane, with some black mica.

From Saxony; Isle of Syra; New Caledonia; Coast region, California (Becker). An epidotic variety is reported from the Alps.

E. HYDROUS MAGNESIAN AND ALUMINOUS ROCKS.

1. Chlorite Schist.—Schistose; color dark green to grayish green and greenish black; but little, if any, greasy to the touch. Consists of chlorite, with usually some quartz and feldspar intimately blended, and often contains crystals (usually octahedrons) of magnetite, and sometimes chlorite in distinct scales or concretions. Metamorphic.

VARIETIES.—a. *Ordinary.* b. *Hornblendic;* the hornblende in grains or needles. c. *Magnetitic.* d. *Tourmalinic.* e. *Garnetiferous.* f. *Pyroxenic.* g. *Staurolitic.* h. *Epidotic.* Graduates into argillyte.

2. Chlorite-Argillyte.—An argillyte or phyllyte consisting largely of chlorite. Metamorphic.

3. Talcose Schist.—A slate or schist consisting chiefly of talc. Not common, except in local beds, most of the so-called "talcose slate" being hydromica schist. *Listwianyte* is a variety, from the Urals, consisting of talc and granular quartz.

4. Steatyte, Soapstone (p. 326).—Consists of talc. Massive, more or less schistose; granular to aphanitic. Color, gray to grayish green and white. Feels very soapy. Easily cut with a knife. Metamorphic.

VARIETIES.—a. *Coarse-granular*, and massive or somewhat schistose. b. *Fine-granular;* "French chalk." c. *Aphanitic*, or *Rensselaerite;* of grayish-white, greenish, brownish to black colors, from St. Lawrence County, N. Y., and Grenville, Canada.

5. Serpentine.—Aphanitic or hardly granular. Easily scratched with a knife. Dark green to greenish black in color, and often a little greasy to the feel on a smooth surface, but sometimes white, pale grayish, yellowish green, and mottled. Metamorphic.

VARIETIES.—a. *Noble;* oil-green and translucent. b. *Common;* opaque, and of various colors. c. *Schistose.* d. *Diallagic;* contains green or metalloidal diallage. e. *Chromiferous;* contains chromite, a chromium ore belonging to serpentine regions. f. *Bastitic;* contains bastite or enstatite. g. *Garnetiferous;* contains garnet, as at Zöblitz. h. *Chrysolitic;* contains chrysolite. i. *Brecciated;* consists of united fragments. (See also page 330.) Serpentine often has a crystalline-granular texture, and sometimes a foliated, which it owes to the mineral from which it was made, as chlorite, enstatite hypersthene, pyroxene, hornblende; which minerals often occur in it in a half-altered state.

6. Ophiolyte. (*Verd-Antique Marble, Ophicalce.*)—A mixture of serpentine with limestone, dolomite, or magnesite, having a mottled green color. Often contains disseminated magnetite or chromite. Metamorphic.

VARIETIES.—a. *Calcareous;* the associated carbonate being calcite. b. *Dolomitic;* the associated carbonate, dolomite. c. *Magnesitic;* the associated carbonate, magnesite. Either of these kinds may contain chromite or magnetite. Handsome verd-antique marble has been obtained near New Haven and Milford, Conn. A beautiful variety, having pure serpentine disseminated in grains or spots through a whitish calcite, occurs at Port Henry, Essex County, N. Y., and is worked.

7. Pyrophyllyte and **Pyrophyllite Slate.**—Like the preceding in appearance and soapy feel, but having the composition of pyrophyllite (p. 328). The color is white and gray or greenish white. Occurs in North Carolina. One of the varieties from the Deep River region is used for slate-pencils. Metamorphic.

The iron ores, hematite, magnetite, limonite, siderite, have rightly a place among rocks, as they constitute beds in the earth's strata. But they have already been sufficiently described.

VI. DURABILITY OF ROCKS.

1. *Sources of Weakness.*—The durability of a rock depends mainly on (1) its degree of porosity or soundness; and (2) the presence or absence of a mineral of easy destruction or easy removal.

The porosity may be general in the rocks, or differ along different planes or laminæ, or be connected in part with the presence of a fissile mineral like mica, or be increased by rifts or cracks. As far within the rock as water and air can gain access *together*, disintegration or decomposition will be going on, whatever the rock. Water by itself protects rocks—as is often seen on rocky seashores where the rock below half-tide may be unchanged, and that above deeply decayed.

The weak mineral of a rock may be—

A. *One that is soluble, and hence removable*, by waters containing either carbonic acid, which is present in all waters, or organic acids, which are always present in waters filtering through soils. Calcite is one such mineral.

B. *One that contains a removable constituent*, such as an alkali or lime, e.g., orthoclase, which loses its potash through infiltrating acid (carbonic or organic) waters, and thence changes to clay or kaolin.

C. One that contains iron in the protoxide state, such iron tending to oxidize further and pass to the sesquioxide state, producing limonite of iron-rust color, or (less frequently) hematite of a red color; e.g., black mica, pyroxene, hornblende.

D. One that contains iron combined with sulphur, which iron tends to pass to the sesquioxide state, as under C; but as the sulphur also oxidizes into sulphuric acid, iron sulphate may result; e.g., pyrite, pyrrhotite, marcasite.

Porosity and the presence of rifts or cracks give an opportunity for these methods of destruction by solution and oxidation to act. In an exposed ledge, the depth to which oxidation, or loss of firmness, extends is an indication of the depth of porosity. In some granites the depth (or the thickness of the *sap*, as the quarryman sometimes calls it) is a yard or more; in the best, a line or less.

The methods of decay are then as follows:

a. By method A: as when a crystalline limestone, if it is a dolomite containing some calcite (p. 460), loses its calcite through infiltrating waters and crumbles to sand—a common fact in Westchester Co., N. Y., Berkshire Co., Mass., and many other regions.

b. By method B: as when a granite has its feldspar weakened or turned to kaolin, and becomes weak or crumbling.

c. By method C: as when granite has its black mica rusted and destroyed, causing the rock to become a granite sand consisting of feldspar and quartz—a common occurrence; or when trap, a rock consisting of a feldspar (labradorite) and pyroxene, becomes changed more or less deeply to rusty rock or rusty earth; the depth hardly a line in the most anhydrous and durable, but many yards in the poorer hydrous kinds.

d. By method D: as when any rock, of the legion containing pyrite, has the pyrite rusted (oxidized) and changed to limonite or hematite, or to sulphate, to the discoloration and decay of the rock—a very common evil in carelessly selected building-stones.

Besides these there are also several mechanical sources of destruction attending methods B, C, D, owing their efficiency to the fact that the introduction of material among grains or into rifts, by chemical change or otherwise, is an introducing of wedges, pushing the grains apart, and opening and extending rifts.

These are the following:

e. In method B, the feldspar loses silica as well as alkali,—at least one third of its 66 p. c.,—and this may deposit about the grains, or in the rifts of the rock deepening and multiplying them, and be so infinitesimal in amount that it is only with difficulty detected.

f. In method C, oxygen is introduced, and the resulting oxide with the rest of the mineral takes more space than the unaltered mineral; and here again there is a wedging or divellent action.

g. In method D, besides the same action as under *f*, the sulphuric acid formed may combine with alkalies, lime, iron, alumina, present in the rock, and make other wedges, besides adding directly in a chemical way to the destructive action.

In addition, there are other mechanical methods of de-

cay which work either molecularly or in the large way. These are:

h. Alternate heating and cooling, from changes in temperature between exposures to sunshine and shadow, day and night, warm seasons and cold, sun's heat on rocks during the day and the cold waters of the returning tide, and so on, causing expansion and contraction, and thence superficial disintegration of granule after granule; or the separation of scales or plates parallel to the surface; or producing a laminated or jointed structure on a large scale, as in some granitoid rocks (e.g., the concentric structure of the Yosemite granite peaks). The unequal expansion caused by a given amount of heat in the different minerals of a granite is supposed to enhance the disintegrating effect.

i. The freezing of water; expansion taking place on freezing (p. 251), exerting a tearing action, both among surface grains and in rifts or fissures, and covering the slopes beneath rocky bluffs in cold climates with débris.

j. The growth of microscopic life (as microbes and minute algæ or fungi) in rifts and pores introduces growing wedges, having a tearing action, extending rifts, etc.

The growth of roots and stems of larger plants wedges open rifts and joints on a large scale, sometimes moving blocks weighing hundreds of tons.

k. Further, organic material, living and dead, is the occasion of destruction by chemical means. The living may give out oxygen and carbonic acid; and the dead may produce by their decay organic acids, carbonic oxide, and carbonic acid. Moreover, the living microbes may, according to their kinds, promote oxidation and deoxidation, nitrification and denitrification, and so be the initiator of change and destruction, as they are of fermentation and decay, and a medium of right functional action in the processes of life.

Rocks have often retained the glacier markings upon them perfectly fresh until now, when they have had a covering of two or three feet of earth; and they have lost such markings after a few years of exposure. This happens often without true decomposition or oxidation. The preservation of the scratches may be due partly to the water of the soil, but also in part, and perhaps most largely, to freedom from the expansion and contraction which is caused by changing temperature.

In granite and sandstone, the less mica the more durable

the rock, because mica tends to increase porosity. In all firm rocks, closeness of texture or fineness of grain is favorable to durability. There is no more durable rock than a good roofing slate. Good granites, when well polished, will usually resist all weathering agencies; because the polished surface has no depressions to catch and hold water, but dries almost immediately after wetting.

To ascertain the durability of a rock, the first step is to examine the rock in its native ledges; if durable there, it will be durable in man's structures, and not otherwise. The practice of testing the durability of a stone for architectural purposes by putting it into water, and then weighing it, after some days of exposure, to see whether it has gained in weight, is a good one. Durability depends much on the climate. In Peru even sunburnt bricks will last for centuries.

2. *Resistance to Crushing.*—The resistance to crushing in rocks is ascertained by subjecting cubes of a given size to pressure; for the best results the pressure should be very slowly applied. In recent experiments by P. Michelot,* Minister of Public Works in France (whose trials numbered over 10,000), the most compact limestones, weighing 2700 kilograms per cubic metre, were crushed by a weight of 900 kilograms per square centimetre. Compact oölitic limestone of Bourgogne and some other French localities, weighing 2600 to 2700 kilograms, bore 700 to 900 kilograms before crushing. Statuary and decorative marbles bore 500 to 700 kilograms.

Of granitic rocks from Brittany, the Cotentin, the Vosges, and the Central Plateau of France, weighing 2600 to 2800 kilograms, the best, which admitted of polishing, bore 1000 to 1500 kilograms; while the coarser granites of Brest and Cherbourg and the syenyte of the Vosges bore 700 to 1000 kilograms; and other coarse granites, in which the large crystals of feldspar were in part decomposed, bore only 400 to 600 kilograms. The green porphyry of Ternuay (Haute Saône), bore 1360 kilograms; the basalt of Estelle (Puy de Dome), 1880 kilograms.

In trials by Gen. Gilmore, trap of New Jersey required to crush it 20,750 to 24,040 pounds a square inch; granite

* Exposition Universelle de 1873 à Vienne, pp. 401–432; and Annales des Ponts et Chaussées, 1863, 1868, 1870.

of Westerly, R. I., 17,750; id. of Richmond, Va., 21,250; syenyte of Quincy, 17,750; marble of Tuckahoe, N. Y., 12,950; id. of Dorset, Vt., 7612; limestone of Joliet, Ill., 11,250; sandstone of Belleville, N. J., 10,250; id. of Portland, Ct., 6950; id. of Berea, O., 8300; id. of Amherst, O., 6650; id. of Medina, N. Y., 17,250; id. of Dorchester, N. B., 9150.

Trials of *Archæan* granites in Minnesota, by Mr. J. Cocroft gave 26,200 pounds per square inch for the mean of 20 samples, and 23,318 pounds when crushed between wooden cushions.

When absorbent rocks are thoroughly wet the weight required to crush them is greatly reduced. Crushing of wet chalk, according to trials by Delesse, required only one third what the stove-dried required; and for the limestone, "calcaire grossier," of Vitry and other localities, mostly one third to one half. Tournaire and Michelot found, for the chalk of the Paris basin, the pressure required when wet two ninths of that required when the rock had been dried at a temperature considerably above 212° F.

ACADEMY MINERAL COLLECTION.

For the convenience of instructors in Academies or High Schools, a catalogue is here inserted of the more desirable species. The collection, made up according to it, would include 125 specimens. The cost will depend on the size and quality of the specimens: with specimens averaging in size 2 × 2½ inches, it need not exceed twenty dollars; and if made forty dollars, it should obtain an excellent collection, the specimens averaging 3 × 3 inches, and many of them crystallized. The number following the name of each mineral is that of the page where described.

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